

DESCRIPTIVE MINERALOGY

WITH ESPECIAL REFERENCE TO THE
OCCURRENCES AND USES OF MINERALS

BY

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PREFACE

This text is based to a large extent upon lectures delivered for a number of years by the author at the University of Michigan. It does not attempt to cover the entire field of Mineralogy, but is to aid the student attending the lectures on Descriptive Mineralogy. Blank pages have been bound into the text so that supplementary notes may be easily added.

The classification followed is essentially the one suggested by Groth according to which the simplest minerals are discussed first and the more complex, especially the silicates and allied compounds, last. Especial emphasis has been placed upon the association, occurrences, and uses of minerals. Where possible, statistics relating to the production in the United States in recent years have been added.

As the text is designed primarily for the student of General Mineralogy very little reference has been made to the microscopic optical properties. Those desiring such data would naturally refer to some of the excellent texts on Optical Mineralogy and Rock Minerals which have been recently published in this country.

Although all possible sources have been drawn upon, no attempt was made to acknowledge the same systematically. A bibliography of the most important and more frequently consulted publications will, however, be found on page VII. For many valuable suggestions and aid in the reading of proof I am indebted to Mr. W. F. Hunt, Instructor in Mineralogy in the University of Michigan; and also to the Ward's Natural Science Establishment, Rochester, N. Y., and the Sullivan Machinery Company, Chicago, Ill., for the loan of several cuts.

Mineralogical Laboratory,
University of Michigan,
September, 1910.

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TABLE OF CONTENTS

	PAGE
Bibliography	VII
Introduction	I
Elements	3
Sulphides and analogous selenium, tellurium, arsenic, antimony, and bismuth compounds	29
Oxides, hydroxides, and oxysulphides	67
Haloids	98
Nitrates, carbonates, manganites, and plumbites	109
Sulphates, chromates, molybdates, tungstates, and uranates	131
Aluminates, ferrites, borates, and so forth	155
Phosphates, arsenates, antimonates, vanadates, niobates, and tantalates	165
Silicates, including titanates, zirconates, and thorates	183
Organic compounds	288
Classification of minerals according to elements	293
Index	319

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INTRODUCTION

Descriptive mineralogy includes a detailed discussion in some systematic order of the crystallographic, physical, and chemical properties as also the associations, distribution, and uses of minerals. In general there are two schemes of classification of minerals. In the one all minerals possessing some element as an important constituent are grouped and described together. Thus all important compounds of iron, hematite Fe_2O_3 , magnetite Fe_3O_4 , limonite $\text{Fe}_4\text{O}_3(\text{OH})_6$, pyrite FeS_2 , siderite FeCO_3 and so forth, would be placed in one group and each described regardless of their chemical and crystallographic relationships. This method is, however, not to be considered as truly scientific. The second method, and the one adopted in this text, groups minerals according to their chemical composition and the important principle of isomorphism. In this way ten classes are easily obtained.

1. Elements.*
2. Sulphides and analogous compounds of selenium, tellurium, arsenic, antimony, and bismuth.
3. Oxides, hydroxides, etc.
4. Haloids.
5. Nitrates, carbonates, etc.
6. Sulphates, chromates, molybdates, tungstates, and uranates.
7. Borates, aluminates, etc.
8. Phosphates, arsenates, etc.
9. Silicates, titanates, etc.
10. Organic compounds.

Within each of the above classes the various species are arranged as far as possible in isomorphous series, thus, bringing together those minerals which possess a similarity in chemical composition and crystal form. All minerals which are considered common are printed in large, heavy type, for example, **PYRITE**. Minerals which are not common but yet important are indicated with smaller type, thus, **Calomel**; while with those which are less important still smaller type is used, for example, **DIOPHASE**.

* This classification is essentially that given by von Groth (see *Tabellarische Uebersicht der Mineralien*, 4th edition, 1898; also French edition of 1904). It does not differ materially from that of Dana (*System of Mineralogy*, 6th edition, 1892).



I. ELEMENTS

The elements may be divided into three groups known as the *non-metals*, *semi-metals*, and *metals*. The *non-metals* include such elements as sulphur, carbon, etc., the specific gravities of which are comparatively low. The *semi-metals* comprise such elements as arsenic, antimony, bismuth and so forth and possess a specific gravity ranging from 5.7 to 10. These elements are not ductile. The *metals* include gold, silver, platinum and so forth. They are usually quite heavy, the specific gravity varying from 7.2 up to 23. These elements are ductile.

There is a pronounced tendency noticeable among the elements to crystallize in the cubic system, especially in the form of the cube, or the closely related form* the rhombohedron of the ditrigonal scalenohedral class of the hexagonal system. The following table showing the number of elements—native and artificial—crystallizing in the different systems is instructive.

Cubic system	12
Hexagonal system	7
Tetragonal system	2
Orthorhombic system	2
Monoclinic system	2
Triclinic system	—

CARBON GROUP

The members of this group are all infusible and comparatively light in weight.

DIAMOND	}	Carbon.
GRAPHITE		
SCHUNGITE		

DIAMOND, Pure Carbon, C.

Cubic, hextetrahedral class. Observed in crystals which may be microscopically small or weigh more than 3,000 carats.† Most commonly observed forms are the octahedron, rhombic dodecahedron, and hexoctahedron; rarer

* Compare, Kraus, Essentials of Crystallography, 1906, page 60.

† The standard of weight for the diamond is the carat which according to locality possesses a different value. Some of these are as follows:

are the cube, tetrahedron, and the tetragonal and trigonal trisoctahedrons. All of the above forms with the exception of the tetragonal trisoctahedron may occur either as independent or predominating forms. Development apparently holohedral. The symmetry of the hextetrahedral class is revealed principally by the etchings and striations observed on the crystal faces. Crystals possessing a distinct tetrahedral habit have, however, been observed. Positive and negative forms are not to be distinguished. Crystals are often rounded and distorted. Twins are common. Two twinning laws have been distinguished. (1) *Supplementary twins*, twinning plane parallel to a face of the cube. Here two tetrahedrons interpenetrate and give rise to a form simulating the octahedron. The characterizing features of such twins are the furrows parallel to the edges of the octahedrons. (2) *Contact twins* according to the Spinel law, the twinning plane being parallel to a face of the octahedron. Polysynthetic twinning according to this law is also to be observed.

Highly perfect cleavage parallel to a face of the octahedron. This is of great value in the cutting of the diamond. The fracture is conchoidal and the hardness the greatest of any known mineral being rated as 10 in Mohs's scale. The hardness, however, varies with the crystal faces. It is greater on the faces of the cube than on those of the octahedron. Also according to Bauer the powder from the surface is harder than that obtained from fragments. Australian diamonds and especially the black diamonds from Borneo are said to be harder than those from South Africa.

Adamantine luster, however, sometimes more or less greasy. Usually

Florence	0.197200 grams
Borneo	0.205000 grams
Leipzig	0.205000 grams
Batavia	0.205000 grams
Spain	0.205393 grams
London	0.205904 grams
Berlin	0.205440 grams
Paris	0.205500 grams
Amsterdam	0.205570 grams
Lisbon	0.205750 grams
Frankfurt a/M.	0.205770 grams
Vienna	0.206160 grams
Livorno	0.215990 grams

The diamond carat as defined by Webster's International Dictionary is $3 \frac{1}{5}$ troy grains or 0.20736 grams. The Century Dictionary places it equal to $3 \frac{1}{6}$ troy grains or 0.2052 grams. The South African diamond carat according to Gardner Williams equals 3.174 grains or 0.20567 grams. In 1877 a syndicate of London, Paris, and Amsterdam jewelers fixed the weight of the carat equal to 3.163 troy grains or 0.205 grams.

transparent, colorless, and water white (*stones of the first water*); yellow, red, gray, brown, green, bluish—rarely blue or black. Doelter thinks that the colors may be caused by small amounts of the oxides of iron, chromium, manganese, or titanium. The streak is ashen gray.

Specific gravity, 3.50 to 3.53. This is similar to that of topaz, 3.4 to 3.6, but differs materially from beryl, 2.7, and quartz, 2.65.

High refractive powers and strong dispersion. $n_{Li} = 2.40735$, $n_{Na} = 2.41734$, $n_{Ti} = 2.46476$. The play of colors (*fire*) so characteristic of the diamond is due to the strong dispersion. Owing to inclusions and internal strains and stresses anomalous double refraction is often observed. On account of internal strains the smoky stones from Kimberley often explode. Excellent conductor of heat, hence, cold to the touch. Poor conductor of electricity. When rubbed becomes positively electrified. Many diamonds when exposed to light or an electric discharge phosphoresce. Transparent to the X rays. This can be made use of in the detection of imitations of lead glass which are opaque to the X rays.

Colorless diamonds are pure carbon for on combustion in oxygen only CO_2 is obtained. Colored stones yield small residues. Dumas and Stass found the residue to be from 1/2000 to 1/500, Erdmann and Marchand 1/1000 of the original weight of the stone. Moissan showed that the residue consists principally of iron, silicon, and calcium. According to Doelter some diamonds may be heated to a comparatively high temperature without injury. Unaffected by acids. Diamond powder is oxidized when heated with potassium bichromate and sulphuric acid. Resorbed by molten "blue ground" of South Africa.

There are three varieties of the diamond, (1) *Diamond proper*, (2) *Bort*, (3) *Carbonado*.

(1) *Diamond*. Known from time immemorial. Often referred to in the writings of the ancients under the name "adamas." These older stones were obtained from secondary deposits in Eastern India, especially on the east side of Deccan. Here the diamond is associated with corundum, beryl, topaz, etc. Borneo also furnished many diamonds. These were the only known localities up to the discovery of the diamond in 1725 in the gold placers in the province of Minas-Geraes, Brazil. A number of provinces of Brazil have yielded diamonds in varying quantities but at present the provinces of Bahia and Minas-Geraes are the most important. Here the diamonds occur in secondary deposits associated with gold, cassiterite, ilmenite, tourmaline, magnetite, pyrope, rutile and so forth. At one time it was thought that the flexible sandstone itacolumite was the parent rock of the diamond. Bahia is also important for the occurrence of carbonado.

The most important locality, now yielding most of the world's production, is South Africa. There are several stories relating to the discovery of the diamonds in this section. According to one of these, an ostrich hunter and peddler named O'Reilly, while traveling in 1867 along the south shore of the Orange river near Hopetown, called at the home of the Boer peasant Schalk van Niekerk. O'Reilly's attention was attracted to several stones with which van Niekerk's children were playing. By agreement O'Reilly took the stones with him for identification. Both were pronounced by Dr. Atherstone of Grahamstown to be diamonds. One weighed $8 \frac{7}{8}$ carats and sold for about \$1,000, whereas the other, being much heavier— $21 \frac{7}{8}$ carats—brought \$2,500. It is also stated that van Niekerk in 1869 brought the now famous "Star of South Africa" upon the market which weighed, uncut, $83 \frac{1}{2}$ carats.

Diamonds in South Africa were first found in secondary deposits, that is, in the sands and gravels of the stream beds. These were called "river diggings." Later in 1870 diamonds were discovered in primary deposits upon the plateau between the Vaal and Modder rivers at the place now known as Kimberley. It was soon observed here that the occurrence of the diamond is restricted to limited areas somewhat elliptical or circular in outline. These areas differ in size and are from 20 to 685 meters in diameter. The usual diameter is about 200 to 300 meters. In these areas the diamonds were found on the surface in a soft yellow ground and being away from the river the occurrence was spoken of as the "dry diggings." Below the yellow ground a rusty colored earth is encountered which in turn is underlain by a hard bluish serpentinous breccia. This bluish serpentinous rock is called the "blue ground." According to Maskelyne the blue ground of the Kimberley mine consists of

SiO ₂	39.73%
Al ₂ O ₃	2.31
FeO	9.69
MgO	24.42
CaO	10.16
H ₂ O	7.55
CO ₂	6.56
Total	100.42

The areas or openings in which the diamonds are found constrict below the surface as indicated in the accompanying cross-section through the Kimberley mine, Figure 1. These openings are often referred to as volcanic pipes or more simply the "pipes." According to Sir William Crookes the diamond in these pipes is associated with no less than eighty

minerals among which pyrope, magnetite, ilmenite, enstatite, diallage, cyanite, augite, pyrite, zircon, chromite, rutile, corundum, olivine, perovskite, and calcite are most important. Pyrope is considered the especially characteristic associate of the diamond. The removal of the diamond from the yellow or rusty ground is readily accomplished by washing. To extract the same from the hard serpentinous breccia it is first necessary to expose the rock to weathering upon the open fields known as "depositing floors."

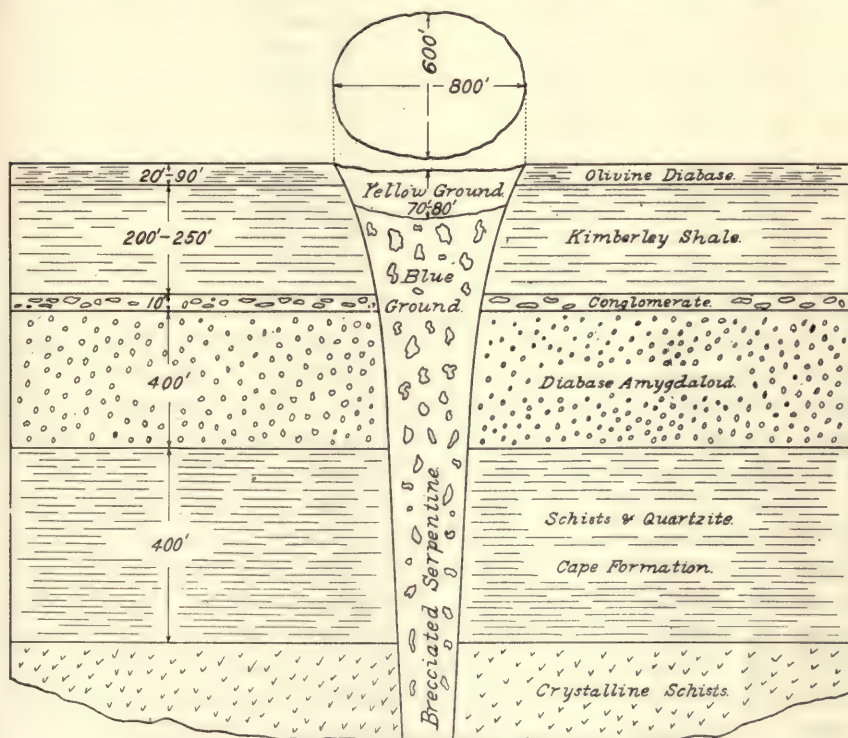


FIG. 1.—Section through the Kimberley Mine.

Here the rock lumps, six to ten inches in diameter, are often sprayed and broken so as to hasten the weathering. From these "floors" the weathered rock is taken to the crushers and washers. At first the concentrates from the washers were sorted by hand but since 1897 they are placed upon an oscillating plate covered with grease, called the "pulsator." Of all the minerals occurring in the pipes the diamond is the only one which sticks to grease. At intervals the grease is removed from the pulsator and the diamonds easily recovered.

The following table, giving the yield in carats per load of rock of

about 730 kilograms, shows that even in the pipes the diamond is not very abundant.

Yield per load at the Kimberley and DeBeers Mines:

1889	1.28 carats
1890	1.15 carats
1891	0.99 carats
1892	0.92 carats
1893	1.05 carats
1894	0.89 carats
1895	0.85 carats
1896	0.91 carats
1897	0.92 carats
1898	0.80 carats
1899	0.71 carats
1900	0.67 carats
1901	0.76 carats
1902	0.76 carats
1903	0.61 carats
1904	0.54 carats

Pipes have been located in several sections of South Africa. Among the most important producing localities the Kimberley, Koffyfontein, Jagersfontein, and the Transvaal Premier districts may be mentioned. Some "pipes" are entirely barren of diamonds, while others contain them but not in sufficient quantities to warrant exploitation.

Among the other localities for the occurrence of the diamond mention may be made of Australia, Ural Mountains, British Guiana, Columbia, and Mexico. In the United States isolated diamonds have been found in several states especially in Wisconsin, Indiana, California, Georgia, North Carolina, Kentucky and Michigan. On August 1, 1906, the most remarkable discovery of diamonds in the United States was made near Murfreesboro, Pike County, about 100 miles south of Little Rock, Arkansas. Here in several months 140 diamonds ranging from 1/16 to 6 1/2 carats in weight were found. They are of various forms and colors. At least one stone was found in a serpentinous matrix, the others in the decomposed rock on the surface. The occurrence being somewhat similar to that of South Africa has attracted wide attention. The region is being thoroughly prospected.

Many theories for the origin of the diamond have been advanced, none of which is, however, wholly adequate. Some of the following are nevertheless of great interest.

Cohen believed that the diamonds were disseminated in the lower crystalline schists and afterwards ejected through the pipes. Later H. Carvill Lewis suggested that the diamonds were formed within the pipes by the action of heat and pressure on hydrocarbons derived from the carbonaceous

shales through which the pipes pass. Gürich, however, suggests that the diamonds did not crystallize in the blue ground but in a rock at lower depths. Hatch and Corstorphine hold that the diamond is an original constituent of a highly basic rock from which the serpentinous breccia was subsequently formed. A. W. Rogers advances a similar view. T. G. Bonney found diamonds in an eclogite rock and hence supposes the same to be the source. Others believe that the diamonds are the result of crystallization from metallic carbides in a basic magma. Even solidification from an aqueous solution on account of the rounded character of the stones and the intimate association with the hydrated silicates, known as the zeolites, has been suggested.

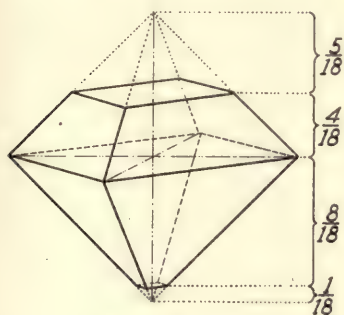


FIG. 2.

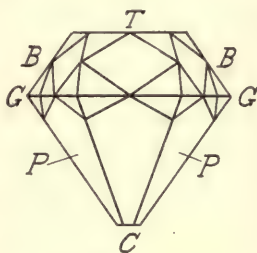


FIG. 3.

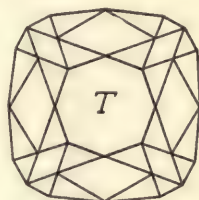


FIG. 4.

T, table; *B*, biset; *G*, girdle; *P*, pavilion; *C*, collet.

The diamond has long been used for many purposes. The ancients satisfied themselves by polishing the natural crystal faces. In 1456 Ludwig van Berquem invented the art of cutting facets on the diamond by means of which the brilliancy or "fire" is greatly increased. Many different styles of cutting have been used. At present but two—the brilliant and rosette—are employed. The brilliant is most common. Natural octahedrons, rhombic dodecahedrons and hexoctahedrons are most easily cut into this form. Figure 2 shows the general method employed in giving the octahedron a brilliant cutting. Figures 3 and 4 show the side and top views of the cut stone. Depending upon the character of the uncut stone from $1/3$ to $1/2$ of its weight is lost in cutting. The important diamond cutting centers at present are Amsterdam, Antwerp, St. Claude, New York, Paris and Hanau.

In 1906 the output of diamonds of the De Beers Consolidated Mines Company and the Premier Diamond Mining Company of South Africa, the world's greatest producers, was about 3,000,000 carats, valued at \$33,247,076. Since 1906, the output has fallen off.

Some famous cut diamonds and their weights are given in the following list:

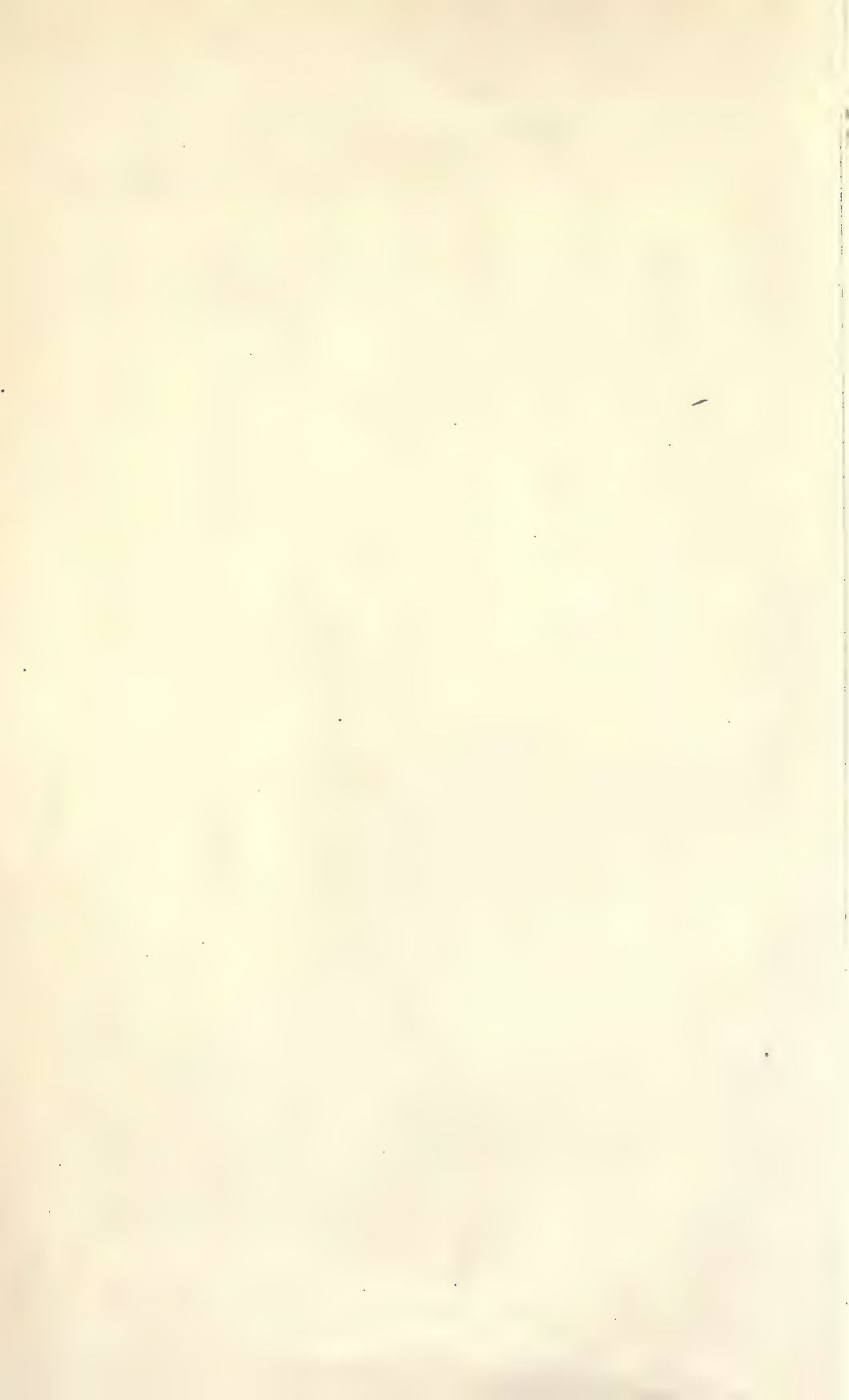
Dresden	76.5	carats
Dresden, green	40.0	carats
Empress Eugenia	51.0	carats
Florentine	133.2	carats
Great Mogul	280.0	carats
Hope	44.5	carats
Jubilee	239.0	carats
Kohinoor, old cutting.....	186.0625	carats
Kohinoor, new cutting.....	106.0625	carats
Nassac	89.5	carats
Orloff	194.75	carats
Pascha of Egypt.....	40.0	carats
Pigott	81.5	carats
Polar Star	40.0	carats
Regent	136.875	carats
Sancy	53.75	carats
Shah	88.0	carats
Star of South Africa.....	46.5	carats
Star of the East.....	25.8125	carats
Star of the South.....	125.5	carats
Stewart	120.0	carats
Tiffany	125.5	carats

The Cullinan diamond was discovered January 25, 1905, in the Transvaal Premier mine about 24 miles northeast of Pretoria.* This diamond is the largest ever found and weighs 3,024.75 carats. It is about 10 x 6 1/2 x 5 centimeters in size and is a distinct cleavage fragment of a larger stone. It is quite colorless, perfectly transparent, free from twinning and contains but few flaws. It is by far the largest diamond ever found. The assembly of Transvaal voted \$1,000,000 for the purchase of the stone in order to present it to Edward VII., King of England.

(2) *Bort*. Also called boart or bortz. This is a semi-crystalline, translucent variety, which is dark in color and usually possesses a radial, fibrous structure. The term is also used to designate stones or fragments which are of an inferior quality and, hence, unfit for gem purposes.

(3) *Carbonado*. This is often called "black diamond" or simply "carbon." This variety is compact, opaque and usually black to gray in color—a dull brown being the prevailing tone. Broken surfaces show a steel gray, brown, greenish gray, and in some cases, a pinkish tinge. The specific

* A description of this mine is given by R. A. E. Penrose, Jr., in *Economic Geology*, 1907, II, 275 to 284.



gravity is 3.15 to 3.29. Carbonado is found only in the placer deposits of the La Chapada and Lavres districts of the Province of Bahia, Brazil. Figure 5 shows a cut of the largest carbon ever found, weight 3,078 carats. Carbonado is used largely in diamond drills and on account of its meager occurrence is of great value, being worth at present, 1907, \$85.00 per carat.

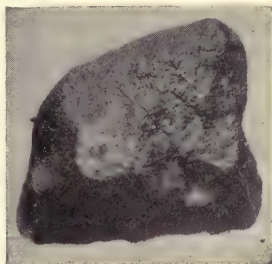


FIG. 5.

As already indicated the crystallized variety of the diamond is used for gem purposes and glass cutters. The powder, obtained from fragments and stones, is employed for grinding and cutting. Recently the diamond, and also bort, have been used in wire-drawing.

Carbonado is used chiefly in the manufacture of diamond core drills, which consist of a line of hollow rods screwed together in sections of varying lengths and rotated by suitable machinery. The lower end of the rods is provided with a bit in which fragments of carbonado are set.

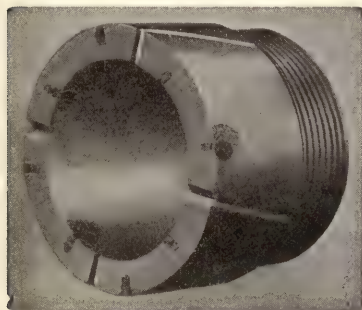


FIG. 6.

Figure 6 shows such a bit. The diamond core drill is of great value in mine prospecting because the core reveals the exact nature of the rocks penetrated. Such test holes have been sunk to great depths by the diamond drill. In 1900 in Rybnik, Upper Silesia, a depth of 6,700 feet was reached, while in South Africa several holes over a mile in depth have been drilled. One of these, drilled in 1905, reached a depth of 6,340 feet.

Bort is also used for grinding and cutting purposes. It has likewise been used in drills but experience shows that carbonado, although much more expensive, gives better results.

GRAPHITE, Plumbago, Black Lead. C.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.3859$. Small, tabular, hexagonal crystals showing basal pinacoid, prism of the first order, bipyramids of the second order and rhombohedrons. Crystals are not common. Usually in foliated, compact, scaly, granular or earthy masses. The earthy or shaly, more or less impure, varieties are commonly termed *amorphous*, the others *crystalline* graphite.

Perfect basal cleavage, giving rise to thin flexible laminae. Greasy feel. Hardness 1 to 2. Specific gravity 1.9 to 2.3. Iron-black to dark steel gray in color with a shiny black streak. Marks paper. Opaque.

Metallic luster, sometimes, however, dull or earthy. Good conductor of electricity. Transparent to the X rays.

Is essentially pure carbon but not as pure as the diamond. Yields sometimes on combustion as high as 20% ash consisting of Fe_2O_3 , SiO_2 , clay and so forth. Not attacked by acids. Infusible.

Occurs in several ways:—large masses and disseminated scales, also in dikes and veins in granites, gneisses, mica schists, and crystalline limestones.

In the United States, Ticonderoga, N. Y., furnishes most of the domestic graphite. Here it occurs as disseminated flakes in crystalline limestone, quartzite, or silicious schist. Graphite also occurs at Byers, Chester Co., Pa., in a decomposed mica schist. Likewise in Alabama, Georgia, North Carolina, New Hampshire and Montana. The earthy, *amorphous* variety occurs in Rhode Island in metamorphic carboniferous rocks.

The largest percentage of the world's supply of graphite is obtained at present from Ceylon. Here it occurs in veins in a garnetiferous granulite and is associated with feldspar, rutile, pyrite, biotite, and calcite. Other important localities are Passau, Bavaria; Steiermark, Austria; Borrowdale, Cumberland; Alibert near Irkutsk, Siberia, formerly a great producer; Pargas, Finland; Misak, Ural Mountains; St. Johns, New Brunswick, and various other localities. Also found in meteorites, for example, the Toluca, Mexico, meteorite.

Graphite is thought in some cases to be the result of metamorphic action upon carbonaceous matter. For the Ceylon deposits the reduction of carburetted vapors, while for the Ticonderoga, N. Y., occurrence formation from volatile or liquid hydrocarbons has been suggested.

Graphite finds extensive application in the manufacture of crucibles, stove polish, paint, lead pencils; lubricants, electrotyping, foundry facings, steam-piping, to color fertilizers, also to color and glaze tea leaves and coffee beans. In 1906 Ceylon exported 40,320 tons valued at \$3,406,550. The production of the United States for the same time was 19,797 tons valued at \$340,239. In 1908 the output was only about 50% as great as in 1906.

Artificial graphite is manufactured by the Acheson Graphite Company at Niagara Falls, N. Y., and is expected to become a successful competitor of the natural product.

SCHUNGITE, C.

Amorphous, black in color with a luster reminding one of anthracite coal. Hardness 3.5 to 4. Specific gravity 1.84 to 1.98. It is hygroscopic and occurs in small quantities in the Huronian schists near Schunga, Government Olonezo, Russia. It is intermediate between anthracite coal and graphite.

SULPHUR, Brimstone, S.

Orthorhombic, bipyramidal class. $a : b : c = 0.8130 : 1 : 1.9037$. Crystals quite common. Mostly showing pyramidal habit; sometimes tabular due to preponderance of the basal pinacoid. Bisphenoidal habit also to be observed especially on crystals from Ciancina, Sicily. Common forms are the basal pinacoid c , unit bipyramid p , modified bipyramid ($1/3 c$) s and the unit brachydome n , Figure 7. Four types of twins have been observed with twinning planes parallel to (1) unit macrodome; (2) unit brachydome; (3) unit prism; and (4) unit bipyramid. Also massive, stalactitic, and in crusts. The massive occurrences may be granular, fibrous, earthy or powdery.

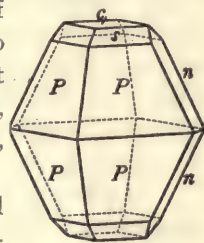


FIG. 7.

Imperfect cleavages parallel to the unit prism, basal pinacoid, and unit bipyramid. Conchoidal to uneven fracture is quite characteristic. Hardness 1.5 to 2.5. Specific gravity 1.9 to 2.1. On crystal faces adamantine luster, otherwise resinous to greasy. Transparent to translucent. White to yellow streak. Usually sulphur-yellow in color, may, however, be straw to honey-yellow, yellow-brown, and due to impurities even reddish, greenish or gray. On rubbing becomes negatively electrified. Non-conductor of electricity and heat. On account of the low conductivity and unequal distribution of heat, crystals often crack when held in the hand. If held near to the ear a crackling sound may be heard.

Usually quite pure. Sometimes contains bitumen, arsenic, selenium and more rarely tellurium. Often contaminated with clay. Heated to 108°C . it melts, at 270°C . it burns with a bluish flame giving rise to SO_2 . Insoluble in water and acids. Easily dissolved by CS_2 .

Sulphur is in general the result of the oxidation of hydrogen sulphide, which may have been formed in several ways. Two types of occurrences of sulphur are usually differentiated depending upon the method of the formation of the hydrogen sulphide, viz: (1) *Solfatara* type and (2) *Sulphate* type.

The *Solfatara* type is of limited importance commercially. Here sulphur is the result of volcanic exhalations, principally H_2S and SO_2 which interact as follows: $2\text{H}_2\text{S} + \text{SO}_2 = 2\text{H}_2\text{O} + 3\text{S}$. In this way the occurrences of sulphur at Naples, Vesuvius, and Aetna in Italy, Iceland, Japan, and the Rabbit Hole district, Nevada, are explained.

The *Sulphate* type is of quite widespread occurrence and furnishes the world's supply. Here, the common sulphates, gypsum $\text{Ca SO}_4, 2\text{H}_2\text{O}$ and celestite SrSO_4 , are reduced by organic matter to the form of the soluble and easily decomposable sulphides which readily yield H_2S . The H_2S on

oxidation then gives rise to native sulphur, as follows: $\text{H}_2\text{S} + \text{O} = \text{H}_2\text{O} + \text{S}$. Sulphur of this type is associated with celestite, gypsum, aragonite, calcite, etc. The most important deposits are at Girgenti, Sicily, and near Lake Charles about 230 miles west of New Orleans, La. Sicily has for many years supplied the world's market almost exclusively but at present Louisiana sulphur is an important competitor. Other localities are Gunnison Co., Colo., Sulphurdale, near Beaver, Utah; Cody, Wyo.; Concil, Spain; Bex, Switzerland; Cracow, Poland; in the salt deposits at Stassfurt, Germany; Sechura, Peru; Rybnick, Silesia; also various places in Japan, Mexico, and Chile. At Maybee, Mich., sulphur is the result of the reduction of celestite. Also as a deposition from hot springs in the Yellowstone Park. Sometimes due to the decomposition of pyrite and other sulphides.

Sulphur is used chiefly in the preparation of the wood pulp for the manufacture of paper. Small quantities are also used in the manufacture of matches, gunpowder, medicines, vulcanized rubber, insecticides, bleaching of silk, straw and woolen materials, etc. On account of the present high price of sulphur, \$19 to \$22 per ton, it is not used as extensively as formerly in the manufacture of sulphuric acid by the chamber process.

Sulphur is polymorphous but the orthorhombic modification is the only one of importance to the mineralogist.

SELENSULPHUR. Volcanite, (S, Se).

Volcanic sulphur containing selenium. Rare. Massive, earthy and fibrous; orange-red or reddish brown crusts associated with sal ammoniac and alum on the islands of Volcano and Lipari. Also on Kilauea, Hawaii.

SELENIUM.

Reported to occur at Culebras, Mexico. Occurrence is doubtful.

ARSENIC GROUP

The members of this series crystallize in the ditrigonal scalenohedral class in pseudo-cubical rhombohedrons. They are brittle and non-malleable.

	<i>a</i> :	<i>c</i>	HARDNESS	SPECIFIC GRAVITY	RHOMBOHEDRAL ANGLE
Arsenic, As.	1 :	1.4025	3—4	5.6—8	85°4'
Antimony, Sb.	1 :	1.3236	3—4	6.6—6.8	87°8'
TELLURIUM, Te.	1 :	1.3298	2.5	6.1—6.3	86°57'
Bismuth, Bi.	1 :	1.3035	2—3	9.6—9.8	87°40'

Arsenic, Native Arsenic, As.

Hexagonal, ditrigonal scalenohedral class. Natural crystals rare and poorly developed showing a cubic or acicular habit. Commonly found in compact, scaly, granular, and fine grained masses with reniform and botryoidal structures. Breaks often into concentric layers.

Perfect basal cleavage. Uneven and fine grained fracture. Brittle. Hardness 3 to 4 and specific gravity 5.6 to 5.8. Metallic luster. Opaque. Color on fresh fracture surface is a tin-white; tarnishes readily to dark gray or black. Streak tin-white.

Arsenic, often contains silver, iron, antimony, bismuth, cobalt, nickel and gold. Volatilizes easily forming arsenic trioxide and yielding the characteristic garlic odor.

Commonly observed associated with silver, cobalt, and nickel ores; thus in the Freiberg, Saxony and the Hartz Mountains districts of Germany; Příbram and Joachimsthal, Bohemia; Kongsberg, Norway; in rhombohedral crystals Akadanimura, Japan; various places in Chile.

Native arsenic furnishes but a small portion of the arsenic used in commerce. Metallic arsenic is a constituent of shot metal. The trioxide is used in dyeing, medicine, calico printing, rodent poisons, glass manufacture, etc.

Antimony. Native Antimony, Sb.

Hexagonal, ditrigonal scalenohedral class. Like arsenic, crystals of antimony are rare. Usually found as compact, granular or lamellar masses. Sometimes radiated and reniform. Perfect basal cleavage. Uneven fracture. Brittle. Hardness 3 to 4. Specific gravity 6.6 to 6.7. Metallic luster. Opaque. Tin-white in color, rarely shows yellow, brown or grayish tarnish colors. Streak tin-white.

Antimony frequently contains silver, arsenic or iron. Easily fusible and volatile.

Native antimony is not common. Sometimes occurs as incrustations, especially on arsenic. Is usually associated with silver and arsenic minerals. The chief localities are St. Andreasberg in the Hartz Mountains; Příbram, Bohemia; Sala, Sweden; Sarawak, Borneo. In comparatively large quantities at Prince William Parish, York Co., New Brunswick.

Native antimony is of no importance commercially. Metallic antimony, obtained from the various compounds of the element, is used in the manufacture of type metal, various alloys, pewter, and anti-friction metals.

TELLURIUM, Native Tellurium, Te.

Hexagonal, ditrigonal scalenohedral class. Prismatic crystals, rare. Usually compact, fine grained or granular masses. Perfect basal cleavage. Brittle but sectile. Hardness 2 to 3. Specific gravity 6.1 to 6.3. Metallic luster and tin-white in color and streak.

Tellurium often contains selenium, gold, and silver.

Of rare occurrence. Usually associated with gold ores. Transylvania; Cripple Creek District, Colo.; Calaveras Co., Cal.

Bismuth. Native Bismuth, Bi.

Hexagonal, ditrigonal scalenohedral class. Pseudo-cubical crystals. Rhombohedral angle $87^{\circ}40'$. Crystals rare. Reticulated, arborescent, in plates, also foliated and compact masses.

Perfect basal cleavage. Brittle, easily pulverized with the hammer. Sectile, somewhat malleable when heated. Hardness 2 to $2\frac{1}{2}$. Specific gravity 9.7 to 9.8. Metallic luster. Opaque. Reddish silver white in color, often shows brassy yellow tarnish color. Shiny metallic lead gray streak.

Bismuth with traces of arsenic, sulphur, tellurium, etc.

Not especially abundant but is always associated with silver, cobalt, and nickel ore deposits, also with lead, zinc, and tin ores. Important occurrences at Schneeberg, Hartz Mountains; Annaberg, Saxony; Joachimsthal, Bohemia; Cornwall, and Devonshire, England; Modum, Norway; Bisperg and Broddbo, Sweden; various places in Chile, Bolivia, New South Wales and New Zealand. Native bismuth also occurs in association with the silver-cobalt-nickel deposits of the Cobalt district, Ontario.

Native bismuth is the source of the metal and its compounds. It is of considerable importance in the manufacture of easy fusible alloys, rifle bullets, and thermo-piles. The compounds are used in medicine. Bismuth is worth about \$1.25 per pound.

AlLemontite, Arsenical Antimony, (As, Sb).

This is an isomorphous mixture of arsenic and antimony in which either element may predominate. Reniform masses usually with irregular lamellar or fine-grained structure. Physical properties similar to those of antimony. Hardness 3 to 4. Specific gravity 6.2. Allemont, France; Příbram, Bohemia; Washoe Co., Nevada; Salpo, Peru.

Tin, Native Tin, Sn.

Reported to occur in the gold placers of Miask, Ural Mountains, and in Guiana, South America. Also in Mexico and in the Clarence River, New South Wales. Very rare. Tin is apparently dimorphous. Artificial crystals belonging to the tetragonal and orthorhombic systems have been observed.

PLATINUM GROUP

The metals of this group form an isodimorphous series. However, only one element, palladium, occurs in both forms. The members of the cubic series are all malleable and possess a hackly fracture while the hexagonal members are brittle and show distinct cleavages. Platinum is the only member of this group which occurs in comparatively large quantities, the annual production being about 6,500 kilograms.



CUBIC SERIES

*(Hexoctahedral Class)***Platinum, Pt.**

IRIDIUM, Ir.

PLATINIRIDIUM, (Pt, Ir.)

PALLADIUM, Pd.

HEXAGONAL SERIES

(Ditrigonal Scalenohedral Class)

IRIDOSMIUM, (Os, Ir.)

OSMIRIDIUM, (Ir, Os.)

PALLADIUM, Pd.

*(Allopalladium.)***Platinum.** Native Platinum, Pt.

Cubic, hexoctahedral class. Small crystals, usually cubes; also octahedrons and rhombic dodecahedrons. Usual occurrence is in scales, grains or nuggets. When found near parent rock these are angular, otherwise rounded. Sometimes the nuggets are of considerable size, two of the largest weighing 8.33 and 9.62 kilograms, respectively.

Metallic luster, opaque. No cleavage. Hackly fracture. Hardness 4 to 6. Malleable, ductile, and sectile. Specific gravity 14 to 19. The presence of varying amounts of iron (specific gravity 7.3 to 7.8) causes the large variation in the specific gravity. Molten platinum has a specific gravity of 19.7, that of hammered platinum is 21.23. The color is silvery-white to dark gray or almost black. May be magnetic, especially if considerable iron is present.

Platinum, but usually containing iron (4 to 19.5%), also iridium, rhodium, palladium, osmium, copper, and at times gold. Platinum with a specific gravity below 16 contains much iron and is termed *iron-platinum*. In normal native platinum the amount of iridium present is usually not over 5% but in *platiniridium* it may be as high as 75%. Infusible at ordinary temperatures, according to Violle not under 1775°C. May be fused and welded in the oxyhydrogen blowpipe. Soluble in hot aqua regia.

Platinum was first discovered in 1735 in the gold placers of the Pinto river, Columbia. Here it is associated with gold, zircon, magnetite, chromite, etc. In 1822 it was discovered in the alluvial deposits of Nijni-Tagilak in the Ural Mountains. Here it occurs sparsely disseminated as scales and grains in an altered and serpentinized peridotite rock. Platinum is also known to occur in the black sands of California, Oregon, Idaho, Colorado, Wyoming, Utah, and North Carolina. Other localities are British Columbia, Ontario, Brazil, New South Wales, San Domingo, and Borneo. It is always associated with chromite.

According to Kemp* native platinum may occur in three ways, viz:

(1) *Placers*. Here the platinum may have been derived from peridotites, also from pyroxenites, gabbros, metamorphosed gabbros, and syenites. It is associated with chromite, magnetite, garnet, menaccanite, zircon, rutile, topaz, small diamonds, quartz, cassiterite, pyrite, gold, copper, iridosmine, and other members of the platinum group.

(2) *Veins*. Platinum has been observed in veins with gold at Tilkerode, Hartz Mountains; Brazil; Columbia; Beresovsk, Russia; and perhaps Broken Hill, New South Wales.

* Bulletin 193, U. S. Geological Survey, 1902.

(3) *Disseminated in eruptive rocks.* Platinum, intimately associated with chromite, is found sparingly in basic eruptive rocks, especially, peridotites, as for example, at Nijni-Tagilak, Ural Mountains.

Platinum is used extensively in the manufacture of physical, chemical, and electrical apparatus, photography, dentistry, jewelry, pyrography, non-magnetic watches, and surgical instruments. In Russia from 1826 to 1844 it was used for coinage purposes. Most of the annual world's supply (about 6,500 kilograms) comes from the Ural Mountains. In 1906 the United States produced about 46,048 grams valued at \$45,189, obtained principally from the black sands of the Pacific slope. In 1908 the output was 23,325 grams, valued at \$14,250. At present, 1910, refined platinum is worth about \$1.00 per gram.

IRIDIUM, Native Iridium, Ir.

Cubic, hexoctahedral class. Small cubical crystals, rare. Usually as grains or scales. Trace of cubical cleavage. Hackly fracture. Metallic luster. Silvery white in color. Hardness 6 to 7. Specific gravity 22.6 to 22.8.

Iridium, with platinum, palladium, or copper. Soluble in cold aqua regia. More infusible than platinum, according to Violle not under 1950°C.

Occurs in platinum placers in the Ural Mountains; Ava, Burma; and Brazil. It is the rarest of the platinum minerals.

Iridium, being the hardest known metal, is often used in small percentages as an alloy to harden platinum and other metals of the platinum group. In this way it is used for standards of weight and measure, wire in standard resistance coils, knife edges for delicate balances, points of gold pens, and bearings in watches and compasses.

Iridium is worth about \$1.00 per gram.

PALLADIUM, Native Palladium, Pd.

Cubic, hexoctahedral class. Small octahedral crystals. Usually in grains, sometimes with radial fibrous structure. Light steel gray color. Hackly fracture. Malleable and ductile. Hardness 4 to 5. Specific gravity 11.3 to 11.8.

Palladium, with platinum and iridium. Most easily fusible of the platinum group of metals. Fuses according to Becquerel between 1360°C. and 1380°C. Soluble in cold aqua regia.

Occurs in Minas-Geraes, Brazil; San Domingo; North Carolina; and in the Ural Mountains.

Metallic palladium is used in the manufacture of delicate scientific instruments, chronometers, watches, and with platinum in photography.

IRIDOSMIUM, Iridosmine, Siserskite, (Os, Ir.)

Hexagonal, ditrigonal scalenohedral class. Small steel to lead gray plates of hexagonal outline. Hardness about 7. Specific gravity 20 to 21.2.

Isomorphous mixture of osmium and iridium with 20 to 30% of iridium corresponding to the formulae IrOs_3 to IrOs_4 . Also contains other metals of the platinum group. When heated loses osmium and affords the characteristic osmium odor. Becomes black when heated in alcohol flame. Heated on platinum foil assumes brilliant colors.

Occurs in small quantities in the platinum placers of the Ural Mountains and California.

OSMIRIDIUM, Hevyanskite, (Ir, Os.)

Hexagonal, ditrigonal scalenohedral class. In tabular hexagonal crystals similar to iridosmium. Tin-white. Hardness 7. Specific gravity 18.8 to 19.5.

Isomorphous mixture of osmium and iridium with 40 to 70% of iridium, corresponding to Ir_4Os . Unchanged before the blowpipe. Attacked by fused potassium nitrate.

Found with platinum in the Ural Mountains; also in Brazil.

Osmiridium is more abundant and lighter in color than iridosmium.



FIG. 8.—Section of Franceville Meteorite, one-half Natural Size.

ALLOPALLADIUM, Native Palladium, Pd.

Hexagonal, ditrigonal scalenohedral class. Small six-sided tabular crystals. Metallic luster. Silver white. Basal cleavage. Brittle. Difficult to file. Occurs in diabase at Tilkerode, Hartz Mountains.

Iron, Native Iron, Fe.

Cubic, hexoctahedral class. Natural crystals unknown. Crystal form shown by artificial and meteoric iron. Usually observed in disseminated grains, scales, plates, or lumps. Perfect cubical cleavage with hackly fracture. Malleable. Hardness 4.5 to 6. Pure iron has a specific gravity of 7.88. Steel gray to iron-black in color. Metallic luster. Shiny streak. Magnetic.

Iron, with varying percentages of carbon, copper, lead, nickel, cobalt and so forth. Infusible before the blowpipe. Soluble in common acids.

Two types of native iron may be distinguished, viz: (a) *terrestrial*, and (b) *meteoric*.

(a) *Terrestrial* iron is of very limited occurrence and may be the result of (1) the action of reducing agents upon iron sulphides or oxides,

or (2) it occurs disseminated in eruptive rocks, doubtless the result of magmatic segregation.

Terrestrial iron of the first type is always free from nickel and occurs at Mühlhausen, Thuringia, also at Pläner near Chotzen, Bohemia. The second type usually contains from 2 to 4% of nickel. The most important occurrence of this character is at Blaafjeld, Ovivak, Disco Island, off the coast of Greenland. Here the terrestrial iron is found in small grains, occasionally in masses of great size, disseminated in basalt. The iron at this locality was formerly thought to be of meteoric origin.

(b) *Meteoric iron.* Many meteorites consist largely of iron, contain, however, varying amounts, 3 to 10%, rarely 20%, of nickel. Small amounts of cobalt are also present. Sections of meteorites, when polished and etched by dilute acid, show several series of parallel lines or bands crossing each other at angles of 60° to 90° . These lines or bands are called the Widmanstätten figures. They are shown in Figure 8 on a section of the Francheville meteorite. The Widmanstätten figures are intimately associated with the crystalline structure of the meteorite in that they represent the more nickeliferous portions which are but slightly attacked by acid.

The metallic iron used so extensively in commerce is derived from the various compounds of iron, principally, hematite, Fe_2O_3 ; magnetite, Fe_3O_4 ; siderite, FeCO_3 , etc.

AWARUITE.

Awaruite is a nickeliferous metallic iron occurring in the sands of the Gorge river, New Zealand.

JOSEPHINITE.

Josephinite is also a nickeliferous iron (Fe , Ni) found in Oregon.

ZINC.

It is rather doubtful whether zinc occurs native. Reported to have been found in Victoria, New South Wales, and New Zealand. Artificial crystals belong to the hexagonal system.

COPPER GROUP

This group contains the so-called precious metals. They are all rather heavy, soft, and malleable, and crystallize in the hexoctahedral class of the cubic system.

LEAD, Pb.

COPPER, Cu.

SILVER, Ag.

Amalgam, (Ag, Hg.)

Mercury, Hg.

GOLD, Au.

GOLD AMALGAM, (Au, Hg.)

LEAD, Native Lead, Pb.

Cubic, hexoctahedral class. Crystals are rarely found. Usually in plates and thin sheets, also in disseminated and loose grains, sometimes filiform. Malleable and ductile. Hardness 1.5. Specific gravity 11.4. Lead gray in color with metallic luster. Opaque. Tarnishes dark.

Practically pure lead, contains sometimes silver and antimony in small quantities.

Of very rare occurrence. Has been found in plates which may be $\frac{1}{2}$ c.m. in thickness in the iron deposits of Pajsberg and Nordmarken, Sweden. As loose grains in the gold placers of Transylvania; Ural Mountains; also reported at Breckenridge and Gunnison, Colorado, and the Wood River District, Idaho.

The metallic lead of commerce is obtained chiefly from galena, PbS ; cerussite, PbCO_3 ; and anglesite, PbSO_4 .

COPPER, Native Copper, Cu.

Cubic, hexoctahedral class. Crystals rather common. The cube, octahedron, rhombic dodecahedron, and tetrahexahedrons (especially $m=4$) are the most common forms. These occur either independently or in combination. A combination of the cube and the tetrahexahedron is quite characteristic of Lake Superior copper, Figure 9. Other combinations are

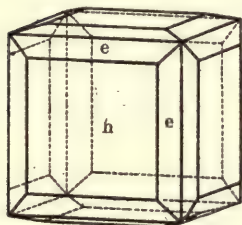


FIG. 9.

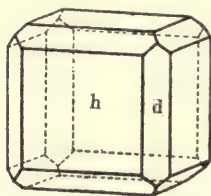


FIG. 10.

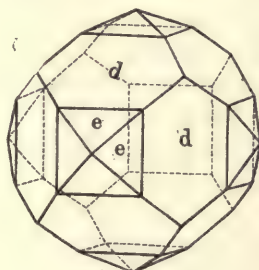


FIG. 11.

shown in Figures 10 and 11. Crystals are often distorted and also show parallel grouping. Twins according to Spinel law. Most commonly observed as scales, plates, and lumps, oftentimes weighing many tons.* Also arborescent and filiform.

Copper has no cleavage but a hackly fracture. Ductile and malleable. Hardness 2.5—3. Specific gravity 8.5 to 9—cast copper 8.83, rolled copper 8.95. Metallic luster. Copper red in color, often with tarnish colors. Red (cuprite, Cu_2O), blue (azurite, $2\text{Cu CO}_3 \cdot \text{Cu (OH)}_2$), green (malachite $\text{Cu CO}_3 \cdot \text{Cu (OH)}_2$), and black (tenorite, Cu O) colors, as a result of decomposition, are often to be observed on the surface of masses of native copper. Streak copper red, metallic and shiny. Good conductor of heat and electricity. Fuses at 1330°C . (V. Riemsdyk.)

Nearly pure copper, but often contains small amounts of silver, bismuth, mercury, arsenic, etc. Easily soluble in nitric acid, the solution turns azure blue upon the addition of ammonia.

* In 1857 a mass of copper $45' \times 22' \times 8'$ weighing 420 tons was encountered in Ontonagon County, Mich., in the mine now known as the Minnesota.

The most important locality for the occurrence of native copper is the Lake Superior region in Northern Michigan. Copper occurs here in three ways, viz: (1) as a cement in a reddish quartz porphyry conglomerate. Here the copper is mostly in the form of scales and grains. (2) Filling the cavities of a dark colored igneous rock known as the melaphyr amygdaloid. In many instances the copper of this type is more or less spherical in form and is then called "shot copper." (3) In masses associated with veins of calcite and the zeolites.* Among the common associates of native copper in this region prehnite, datolite, analcite, quartz, epidote, laumontite, calcite, and native silver may be mentioned.

Inasmuch as the copper of the Lake Superior region is the result of deposition from solution it is thought that the igneous rocks must be considered as the source of the metal. These rocks contain minerals which often show small amounts of copper and by their decomposition and interaction with a solution of ferrous salts the deposition of metallic copper may have resulted. Recently Fernekes† has shown experimentally that three factors may have been important in the deposition of native copper, namely, the presence of (1) copper chloride or some copper silicate and hydrochloric acid, and (2) calcium and sodium silicates, and (3) minerals containing ferrous iron.

In 1908 the Lake Superior region produced 222,289,584 pounds of copper. This was about 22% of the total output of the United States or 13% of the world's production for that year. Among the largest mines of this section the following with the production for 1908 may be mentioned.

	POUNDS
Calumet and Hecla	88,124,007
Osceola	21,250,794
Quincy	20,600,361
Champion	17,786,763
Baltic	17,724,854
Tamarack	12,806,127
Mohawk	10,295,881
Wolverine	9,555,233
Trimountain	6,034,908

The ores of the Lake Superior region contain about one per cent of copper and are easy to treat. By means of crushing, washing, and concentrating with jigs and tables the metallic copper is readily extracted. It is

* A group of silicate minerals containing water of crystallization.

† A. C. Lane. The Formation of Lake Superior Copper. Science, 1907. N. S. XXV, 589. Also G. Fernekes, Precipitation of Copper, etc. Economic Geology, 1907, II, 580.

then melted, refined, and cast into ingots. A small amount of "lake" copper is also refined electrolytically.

Copper also occurs in veins and deposits associated with the various copper minerals, azurite, malachite, cuprite, chalcopyrite, bornite, chalcocite, etc. Some of the other localities for the occurrence of native copper are the Ural Mountains, Siberia; Nassau, Germany; Cornwall, England; Chile; Bolivia; Peru; Brazil, and Australia. In small quantities in various places in Massachusetts, Connecticut, New Jersey, California; more abundantly in Arizona and New Mexico.

Metallic copper, as is well known, is used very extensively in commerce. It is worth, April 1910, about 13 cents per pound. Large amounts are used in the manufacture of copper wire, nails and sheets, various alloys, electrical apparatus, also for coinage purposes and chemical reagents.

SILVER, Native Silver, Ag.

Cubic, hexoctahedral class. Cube, octahedron, rhombic dodecahedron and tetrahexahedron ($m=2$) are most commonly observed as independent or predominating forms. Crystals are very small and often distorted. Twins according to the Spinel law. Also acicular, reticulated or arborescent. Often fine threads or wires, sometimes matted resembling tufts or wads of hair or moss. Masses, plates, and scales.

No cleavage but malleable and ductile. Hardness 2.5 to 3 and specific gravity 10 to 12; pure 10.52. Metallic luster. Color silver white, usually with yellow brown, gray or black tarnish colors. Thin sheets appear blue in transmitted light. Streak metallic silvery white. Excellent conductor of heat and electricity.

Silver, usually with varying amounts of gold, as high as 28%, furthermore copper, arsenic, antimony, mercury, iron, platinum, etc. Easily fusible, also soluble in nitric acid.

Occurs commonly with ores of silver, lead, arsenic, cobalt, and nickel. The usual gangue minerals are calcite, quartz, barite, and fluorite. In many cases silver is the result of the reduction of argentite Ag_2S , cerargyrite Ag Cl , pyrargyrite Ag_3SbS_3 , proustite Ag_3AsS_3 and so forth. Kongsberg, Norway, has furnished a great deal of silver in the form of crystals and large masses up to 750 pounds. The Saxon mines at Freiberg, Marienberg, and Annaberg have long been heavy producers. Also Joachimsthal, Bohemia; Ural Mountains; Mexico, especially Sonora, Durango, and Sinaloa; Chile; Peru; and Bolivia.

In the United States native silver is found rather extensively in Colorado, Montana, Utah, Idaho, Arizona, Nevada, and California. In the Lake

Superior Copper region it occurs in masses with copper forming the so-called "half-breeds."

At Cobalt, Ontario, large deposits of native silver associated with cobalt and nickel ores were discovered in 1903. Here the deposits occur in narrow veins in slightly inclined metamorphosed fragmental rocks and diabase of Huronian and Keewatin ages. Many large lumps of silver, about 95% pure, have been found. Some of these masses weighed from 600 to 1000 pounds. The chief associates of silver in this district are niccolite, chloanthite, smaltite, cobaltite, erythrite, annabergite, native bismuth, and so forth. The output for 1909 was 26,364,703 ounces, valued at \$12,941,978.

Rarely found in placer deposits. It is too easily acted upon by circulating water. Nevertheless, nuggets valued at over \$150,000 have been recovered from the bottom of Cobalt Lake, Ontario.

Native silver is used for coinage, jewelry, photography, ornamental purposes, also in chemical, physical, and surgical apparatus. Silver is worth about 52 cents per ounce.

Amalgam, Native Amalgam. Silver Amalgam, (Ag, Hg.)

Cubic, hexoctahedral class. Rhombic dodecahedron and tetragonal tris-octahedron ($m=2$) are usually the predominating forms; other observed forms are the cube, octahedron, tetrahedrons, and hexoctahedron ($n=3/2$, $m=3$). Also as disseminated grains; plates, and coatings.

Brittle, metallic luster. Silver white in color. Hardness 3 to 3.5. Specific gravity 13.7 to 14.1. Streak silvery white. Conchoidal or uneven fracture. Opaque.

Isomorphous mixture of silver and mercury in varying proportions. The following formulae indicate the great variation in composition Ag_2Hg_3 to Ag_{36}Hg . Heated on charcoal or plaster tablet the mercury volatilizes leaving a globule of silver.

Not very common. Found principally in association with native mercury and cinnabar, thus at Moschellandsberg, Bavaria; Almaden, Spain; Kongsberg, Norway; Chañarilla, Chile; Sala, Sweden, and so forth.

Does not occur abundantly enough to be important commercially.

Mercury, Native Mercury, Quicksilver, Hg.

Cubic, hexoctahedral class. At ordinary temperature mercury is a liquid, at -38.5°C . to -39.44°C . it solidifies and crystallizes in the form of the octahedron with a specific gravity of 15.19 (Joule). Usually found as small drops or globules associated with the various mercury minerals, especially cinnabar and calomel.

Brilliant metallic luster. Tin white in color. Opaque. Very heavy, specific gravity 13.5 to 13.6. Boils at 357°C .

Nearly pure, may contain a little silver. Easily volatile.

Native mercury does not occur commonly. The most important localities are Almaden, Spain; Idria, Austria; Moschellandsberg, Bavaria; Avala, Siberia; New Almaden, and San José, California; and Terlingua, Texas.

Mercury is sometimes deposited by hot springs; thus in New Zealand, California, and Nevada.

Most of the mercury of commerce is obtained from cinnabar, HgS . In 1906 the United States produced 28,293 flasks of $76\frac{1}{2}$ pounds each valued at \$1,157,184. Metallic mercury is used extensively in the amalgamation of silver and gold ores, also in industrial chemistry, medicine, electrical apparatus, dentistry, scientific apparatus of various types, mercury vapor lamps and so forth.

GOLD, Native Gold, Au.

Cubic, hexoctahedral class. Crystals are usually small, more or less distorted, and possess dull faces. The most common forms are the octahedron, cube, and rhombic dodecahedron. These may occur independently or in combination with one another. Other forms are the tetragonal tris-octahedrons ($m=2$, $m=3$), and the tetrahexahedron ($m=2$). Skeletal development common. Twins according to the Spinel law. Most common occurrence is as disseminated scales or grains. Also filiform, reticulated, and in large lumps or nuggets. Several nuggets weighing as much as 190, 210, 237, and 248 pounds have been reported from the Donolly district in Australia.

Malleable and ductile metal. No cleavage, hackly fracture. Hardness 2.5 to 3 and specific gravity 15.6 to 19.3. Metallic luster. Golden, brassy to light yellow in color and streak. Opaque.

Gold, usually contains varying amounts, up to 40%, of silver; also iron, copper, bismuth, palladium, rhodium and so forth. Readily fusible and soluble in aqua regia. Readily acted upon by nascent chlorine forming the soluble chloride. Also rendered soluble by the action of potassium cyanide and oxygen. Forms an amalgam with mercury.

Gold is widely distributed but in only a comparatively few places in sufficient quantities to be of economic importance. There are two general types of occurrence, viz: (1) *In situ*, and (2) in *secondary deposits* called *placers*.

Gold occurring *in situ* is usually found in connection with quartz veins or deposits of irregular shape in igneous and metamorphic rocks of varying ages. Among these rocks mention may be made of talcose, chloritic, argillaceous, mica, and hornblende schists, gneiss, diorite, porphyry, granites, trachytes and andesites. In some cases the gold occurs as small but distinctly visible particles and is then termed *free milling*, or it may be invisible and its presence revealed only by assaying. The common associates of gold in quartz veins are pyrite, galena, sphalerite, chalcopryrite, arsenopyrite, tellurides, arsenic, bismuth, tetrahedrite, stibnite, magnetite, hematite, barite, fluorite, siderite, and so forth. Of these associates pyrite, chalcopryrite,

galena, tetrahedrite, sphalerite and arsenopyrite are often auriferous. Owing to the decomposition of the various associated sulphide minerals, especially pyrite, the quartz, where exposed to the surface and the action of percolating waters—zone of oxidation—is usually more or less cellular and of a rusty appearance. Such quartz is often called “porous” or “rusty” quartz and in it the gold is usually of the *free-milling* type.

Free milling gold is easily extracted from the gangue by means of crushing and washing in a stamp mill and subsequent amalgamation with mercury. The low grade ores and also the auriferous sulphides are usually roasted and then treated by either the chlorination or cyanide processes. In the chlorination process the auriferous ores are subjected to the action of nascent chlorine, which may be prepared in various ways. This gives rise to a solution containing gold chloride, AuCl_3 , from which the gold is then easily precipitated either as the metal or sulphide by ferrous sulphate or hydrogen sulphide, respectively. The cyanide process makes use of a weak solution of potassium cyanide and atmospheric oxygen. The finely crushed and roasted ore is placed in large receptacles through which a weak solution of potassium cyanide flows. In time the gold passes into solution as the double cyanide, KAu Cy_2 , and is then readily precipitated by either metallic zinc or electrolysis.

Placer gold is the result of the disintegration of the rocks containing gold in situ, that is, disseminated or in veins. The rocks, owing to the action of the atmospheric agencies—heat, cold, rain, etc.—and erosion, are reduced to sand and gravel. The gold on account of its high specific gravity becomes concentrated in the stream beds in auriferous regions and is found as scales, grains, and nuggets. Many such occurrences of great value are known. Placers may be ancient, recent, or present, depending upon the geological period in which they were formed. The older placers are often more or less consolidated or protected by means of overlying igneous rocks. Ancient placers occur in California, Australia, New South Wales, South Africa, and in the Black Hills of South Dakota. Recent placers are found in the Klondike district, Alaska; Colorado; California; Australia; Siberia; and so forth. Present placers are those being formed at the present time and occur along the seacoast at Cape Nome, Alaska, and elsewhere. In nearly all noteworthy gold producing districts, gold has usually been found first in placer deposits and subsequent exploration revealed the primary occurrences in situ.

Placer gold is readily obtained by washing. Usually the sand and gravel is thrown into long wooden troughs called sluices. Through these sluices water flows at a rather rapid rate in order to carry away the lighter rock material. At definite intervals cross-bars, called riffles, are placed in

the trough so as to check to some extent the velocity of the water and thereby the transporting power also. This causes the heavy particles to fall to the bottom of the sluices and since mercury is added from time to time and is also caught by the riffles, an amalgam of gold is formed. From this amalgam the gold is easily obtained by volatilizing the mercury.

In some localities hydraulic mining is employed in working placer deposits. This does not differ essentially from the above method and consists in directing a large stream of water under high pressure against a bank of the placer in order to loosen the same and wash the sand and gravel down into the sluices.

At present, 1907, the most important gold producing localities are (1) the South African, which includes Transvaal, Rhodesia, and the West Coast. Here the gold occurs in both veins and secondary deposits. (2) The United States, with Colorado, Alaska, California, Nevada, S. Dakota, Utah, and Montana as the largest producers in the order named. The Cripple Creek district of Colorado; the Black Hills of South Dakota; Goldfield and Tonapah, Nevada, and Klondike, Alaska, are all well known gold fields. (3) Australia and New Zealand. Here Victoria is the largest producer. The occurrences are both in situ and in placers. (4) Russia, principally in the Ural Mountains, Canada, Mexico, Hungary, Brazil, British India, and Chile also have important deposits.

In 1908 the world's production of gold amounted to 21,529,300 ounces or 669,651 kilograms,* valued at \$444,382,312. The ten largest producers were:

	OUNCES	VALUE
South Africa	7,928,348	\$163,869,954
United States	4,659,360	96,313,256
Australasia	3,557,705	72,509,200
Russia	1,497,076	30,944,561
Mexico	1,187,445	24,518,548
British India	504,309	10,424,067
Canada	462,467	9,559,274
China	250,000	5,165,000
Japan	155,000	3,203,850
Columbia	170,000	3,514,073

Gold occurs in small quantities in ocean water. According to Sonstadt and Liversidge a ton of ocean water near Sidney, Australia, contains 0.032 to 0.064 grams of gold. Repeated attempts have been made to extract gold from the ocean.

Gold is used chiefly for coinage and jewelry, also to some extent in

* Gold is worth \$20.67 per troy ounce or \$664.55 per kilogram.



photography. Gold coins of the United States consist of nine parts of gold and one of copper. For jewelry purposes copper and silver are alloyed with gold. The gold content of such alloys is expressed in carats, thus 14 carat gold consists of 14/24ths gold and 10/24ths other metals.

GOLD AMALGAM, (Au, Hg, Ag.)

Contains aside from small percentages of silver (about 5%) as high as 41.63% of gold. It is white in color and has a metallic luster. Occurs usually in friable grains, sometimes in globules, rarely crystallized. Specific gravity about 15.5. Not common. Reported only from Mariposa, California; platinum placers of Columbia: and Victoria, Australia.

II. SULPHIDES

AND ANALOGOUS SELENIUM, TELLURIUM, ARSENIC, ANTIMONY, AND BISMUTH COMPOUNDS

I. SULPHIDES, ETC., OF THE METALLOIDS

Here are placed all metallic compounds without oxygen of sulphur, antimony, bismuth, selenium, tellurium, and arsenic. They are usually rather heavy, possess a metallic luster and are opaque. Some of the minerals of this class are of great importance as ores.

REALGAR, AsS .

Monoclinic, prismatic class. $a : b : c = 1.4403 : 1 : 0.9729$, $\beta = 113^\circ 55'$. Crystals are usually short prismatic; also in coarse or fine granular and compact masses. As an incrustation or coating on various minerals.

Hardness 1.5 to 2. Specific gravity 3.4 to 3.6. Perfect cleavages parallel to the clinopinacoid and orthoprism. Fracture is conchoidal. Resinous or greasy luster with an aurora-red or orange-yellow color. Transparent to translucent.

AsS , or sometimes written As_2S_2 , assuming the constitution to be $\text{S}=\text{As}-\text{As}=\text{S}$. Very easily fusible before the blowpipe. Yields a blue flame and dense white fumes with the odor of garlic and sulphur dioxide. Yields a red sublimate in closed tube. Partially soluble in potassium hydroxide.

Realgar is usually associated with orpiment; occurs, however, also with ores of silver, lead, and antimony. Sometimes found as a sublimation product on Vesuvius and Solfatara. In the Yellowstone Park as a deposit from hot springs. Some notable localities are Nagyág and Joachimsthal, Bohemia; Kapnik and Felsöbánya, Hungary; Binnenthal, Switzerland. Various places in Utah and California. Formed in various metallurgical processes.

The artificial compound finds application in the manufacture of fireworks and pigments.

ORPIMENT, Auripigment, Arsenical Gold Ore, As_2S_3 .

Monoclinic, prismatic class. $a : b : c = 0.5962 : 1 : 0.665$, $\beta = 90^\circ 41'$. Crystals are short prismatic, but not common. Usually in foliated or granular masses. Sometimes as reniform crusts.

Hardness $1\frac{1}{2}$ to 2. Specific gravity 3.4 to 3.5. Perfect cleavage parallel to clinopinacoid. Flexible. Resinous to pearly luster. Lemon yellow in color and streak. Translucent to opaque. Very much like realgar but differs in color.

As_2S_3 . When heated becomes red, otherwise like realgar.

Occurs with realgar from which it has often been formed. Results from the decomposition of arsenic compounds such as proustite, tennantite, or enargite. Principal localities are Tajowa, Hungary; in large masses at Allchar, Macedonia; Julamerik, Kurdistan. Also at Mercer, Iron Co., Utah; San Bernardino Co., California; Douglas Co., Oregon. As a deposit from hot springs at Steamboat Springs, Nevada, and in small quantities with realgar in the Yellowstone Park.

The artificial compound is used as a pigment, also in dyeing and tanning processes. Mixed with potassium hydroxide and quicklime it forms a paste for the removal of hair from the skins.

STIBNITE GROUP

This group contains the sulphides and selenides of antimony and bismuth which conform to the general formula $\text{M}'''\text{R}_3$. The members of this group crystallize in the orthorhombic bipyramidal class.

	a	:	b	:	c
STIBNITE , Sb_2S_3	0.9926	:	1	:	1.0179
BISMUTHINITE , Bi_2S_3	0.9680	:	1	:	0.9850
GUANAJUATITE , $\text{Bi}_2(\text{Se},\text{S})_3$ approx.	1	:	1	:	?

STIBNITE, Antimonite, Gray Antimony, Antimony Glance, Sb_2S_3 .

Orthorhombic, bipyramidal class. $a : b : c = 0.9926 : 1 : 1.0179$. Crystals common, prismatic and highly modified. Over 90 forms have been noted. Crystals often show vertical striations; also may be twisted or bent. In needle-like crystals arranged radially. Bladed and columnar. Occurs in coarse and fine grained masses. Compact.

Perfect cleavage parallel to brachypinacoid. Slightly sectile. Metallic luster. Hardness 2. Specific gravity 4.6 to 4.7. Lead gray in color and streak. Often tarnishes black.

Sb_2S_3 . Fuses easily in candle flame. Sometimes auriferous or argenterous. Colors flame greenish blue and yields dense fumes of antimony trioxide.

Found in veins, with quartz and various antimony minerals which result from the decomposition of stibnite. Also with galena, lead and silver ores, barite, cinnabar, sphalerite, gold, etc. Important localities are Wolfsberg, Hartz Mountains; Mieschau, Bohemia; Arnsberg, Westphalia; Magurka in granite, Kremnitz and Felsöbánya in andesite, Hungary; Kostainik, Siberia; also in Algeria, Asia Minor, Borneo, Mexico. Excellent crystals from Shikoku, Japan.

In the United States in 1906 ores were shipped from Shoshone Co., Idaho; Austin and Battle Mt., Nevada; Garfield Co., Utah; and Okanogan Co., Washington. Other deposits occur in Sevier Co., Arkansas; Kern and Benito Counties, California; Iron Co., Utah. Most of the world's supply is obtained from France, Algeria, and Italy.

Stibnite is the chief source of metallic antimony and its compounds. It is used in pyrotechny, safety matches, rubber goods, and percussion caps.

BISMUTHINITE, Bismuth Glance, Bi_2S_3 .

Orthorhombic, bipyramidal class. $a : b : c = 0.968 : 1 : 0.985$. Very much like stibnite. Well developed crystals are rare. More commonly in bunches of acicular crystals; also in foliated, radial and granular masses.

Perfect cleavage parallel to brachypinacoid. Color lead gray to tin white, usually lighter than stibnite. Yellow or iridescent tarnish often to be observed. Metallic luster. Hardness 2 and specific gravity 6.4 to 6.6. Lead gray streak.

Bi_2S_3 . Fuses easily. Gives with various reagents characteristic bismuth reactions. Sometimes copper, iron, or selenium are present.

Not nearly as common as stibnite. Usually with tin ore deposits; also in silver-cobalt veins. Schneeberg, and Altenberg, Saxony; Joachimsthal, Bohemia; Cornwall, England; New South Wales; Queensland. With silver-tin-bismuth deposits in Bolivia; Sinaloa, and Guanajuato, Mexico.

In the United States with gold at Rowan, North Carolina; with garnet and barite in Beaver Co., Utah; also in Mono and Fresno Counties, California.

GUANAJUATITE, Frenzelite, $\text{Bi}_2(\text{Se}, \text{S})_3$.

Needle-like crystals; also granular, fibrous, foliated, or massive. Looks like bismuthinite. Hardness 2.5 to 3.5. Specific gravity 6.25 to 6.62. Color bluish gray. Distinct brachypinacoidal cleavage. Occurs at Guanajuato, Mexico.

TETRADYMIT, $\text{Bi}_2\text{Te}_2\text{S}$.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.587$. Small crystals. Those from Shubkau near Schemnitz, Hungary, show cyclic fourlings; twinning plane parallel to $-\frac{1}{2}R$. Usually in foliated or granular masses. Perfect basal cleavage. Hardness 1.5 to 2. Marks paper. Specific gravity 7.2 to 7.9. Light lead gray color; upon fracture surface a strong metallic luster, otherwise dull.

$\text{Bi}_2\text{Te}_2\text{S}$. Sometimes contains selenium. Composition may vary but in general indicated by the formula given. Fuses readily and reacts for bismuth, tellurium, and sulphur.

Of rare occurrence. With gold, Schubkau near Schemnitz, Hungary; also other localities in Hungary. In the United States in Spottsylvania Co., Virginia; Davidson, Burke, and McDowell Counties, North Carolina; also in Montana, Colorado, and Georgia.

Molybdenite, MoS_2 .

Hexagonal, dihexagonal bipyramidal class. $a : c = 1 : 1.908$. Well developed crystals very rare, on account of softness faces are easily destroyed. Usually in disseminated scales or grains; sometimes in foliated or granular masses.

Excellent basal cleavage. Flexible, greasy. Marks paper. Blue gray in color (graphite is black). Hardness 1 to 1.5. Specific gravity 4.7 to 4.8 (graphite 1.9 to 2.3). Gray streak on paper, on glazed porcelain greenish (graphite shiny black).

MoS_2 . Sometimes auriferous or argenterous. Reacts for molybdenum and sulphur.

Most important molybdenum mineral. Generally disseminated in granites, especially those associated with tin ore deposits, also in syenites, gneisses, and crystalline limestones.

Large crystals in Renfrew Co., Canada; Cornwall, England; Altenberg, Saxony; Scandinavia; Finland; Ural Mountains. In the United States in many localities along Appalachian, Rocky, and Sierra Nevada Mountains. At present but two localities in the United States have been exploited, namely, Crown Point, Chelan Co., Washington, and Cooper, Washington Co., Maine.

Chief source of molybdenum and its compounds. Used in the manufacture of molybdenum steels.

2. SULPHIDES, ETC., OF THE METALS

SPHALERITE—WURTZITE GROUPS

The bivalent metals calcium, zinc, cadmium, manganese, iron, and nickel form with one atom of sulphur an isodimorphous series. The one group of this series crystallizes in the cubic system and has as its most important representative sphalerite, ZnS . The other group crystallizes in the hexagonal system.

The isodimorphous series is as follows:

SPHALERITE GROUP

(Cubic System)

OLDHAMITE, CaS.

SPHALERITE, ZnS.

Alabandite, MnS.

TROILITE, FeS.

Pentlandite, (Fe, Ni)S.

Hextetrahedral Class

Hextetrahedral Class

WURTZITE GROUP

(Hexagonal System)

		<i>a</i>	:	<i>c</i>
WURTZITE, ZnS.	Ditrigonal Pyramidal Class	1	:	0.9353
ERYTHROZINCITE, (Zn,Mn)S.	Ditrigonal Pyramidal Class			?
Greenockite, CdS.	Ditrigonal Pyramidal Class	1	:	0.9364
PYRRHOTITE, FeS.?	Ditrigonal Pyramidal Class	1	:	0.9528
Millerite, NiS.	Ditrigonal Pyramidal Class	1	:	0.9886
Niccolite, NiAs.	Ditrigonal Pyramidal Class	1	:	0.9462
ARITE, Ni(As,Sb).	Ditrigonal Pyramidal Class			?
BREITHAUPITTE, NiSb.	Ditrigonal Pyramidal Class	1	:	0.9062

OLDHAMITE, CaS, is a rare mineral. It has been observed in small quantities in several meteorites.

SPHALERITE, Blende, Zinc Blende, Black Jack, ZnS.

Cubic, hextetrahedral class. Crystals are common. Often distorted. The tetrahedrons, rhombic dodecahedron, and the trigonal tristetrahedron ($m=3$) are the most commonly observed forms, Figures 12, 13, and 14.

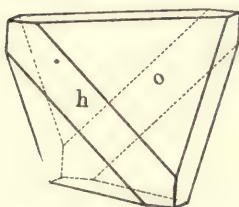


FIG. 12.

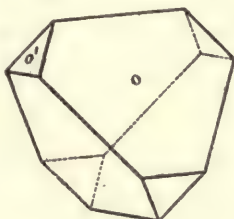


FIG. 13.

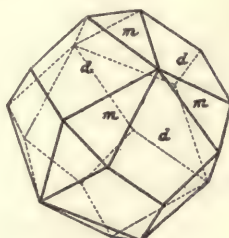


FIG. 14.

Crystals are often highly modified. Twins are very common. The twinning plane is parallel to a face of the octahedron. Polysynthetic twinning is also to be observed. Also occurs in cleavable, fine and coarse grained masses; compact, foliated, fibrous, and more rarely in radiated and botryoidal masses.

Very perfect rhombic dodecahedral cleavage. Conchoidal fracture. Brittle. Resinous to adamantine luster. High index of refraction, $n_{\text{Na}} = 2.3692$. Hardness 3.5 to 4. Specific gravity 3.9 to 4.2. Color varies greatly. When pure it is white. Depending upon impurities it may be brown, red, green, yellow, black, and so forth. Transparent to translucent. Sometimes phosphoresces when broken or rubbed. Streak brown, light yellow or white.

ZnS, but may contain varying amounts of iron, manganese, cadmium, lead, tin, mercury, gold, silver, indium, gallium, or thallium. The amount of iron present may be as high as 18%. The other elements are usually present in comparatively small amounts. Fuses with difficulty. On charcoal gives a zinc coating. Soluble in nitric acid with the separation of sulphur; in hydrochloric acid with the evolution of hydrogen sulphide.

Occurs extensively in dolomitic limestones and other sedimentary rocks, also in crystalline rocks. Usually associated with galena, chalcopyrite, calcite, dolomite, barite, fluorite, marcasite, siderite, rhodochrosite, and quartz. Common in silver and lead localities. Sphalerite has doubtlessly been deposited in many instances by precipitation from aqueous solutions. Hence it is found in veins, cavities, and sometimes in extensive deposits.

Commonly observed in Freiberg, Saxony; in dolomite at Binnenthal, Switzerland; Kapnik, Hungary; Cornwall, England; Příbram, Bohemia; etc., etc.

In the United States it is especially common in the limestones of Missouri, Wisconsin, Iowa, and Illinois, usually associated with galena and calcite. Beautiful crystals at Mineral Point, Wis., and Joplin, Mo. At Franklin Furnace, N. J., a more or less colorless variety—*cleiophane*—occurs. Sphalerite is also found in many other localities.

Sphalerite is used as an ore of zinc. Most of the cadmium, used in commerce, is obtained from sphalerite. It is also used to some extent in the manufacture of zinc sulphate.

Alabandite, Manganblende, MnS.

Cubic, hextetrahedral class. Crystals are rare. The cube, rhombic dodecahedron, tetrahedrons, and trigonal tristetrahedron ($m=2$) are the commonly observed forms. Usually in granular masses. Perfect cubical cleavage. Hardness 3.5 to 4. Specific gravity 3.9 to 4. Opaque. When fresh alabandite possesses a submetallic luster; usually, however, due to tarnish it is more or less dull. Gray black in color, tarnishes to a brown black. Dirty green streak.

MnS. Fuses with difficulty. Reacts for manganese and sulphur. With hydrochloric acid evolves hydrogen sulphide.

Not very abundant. With rhodochrosite at Kapnik, Hungary; Nagyág, Transylvania; Mexico; Peru; and Brazil.

In the United States in Summit County, Colorado; also at Tombstone, Arizona.

TROILITE, FeS , occurs in brownish masses in meteorites.

Pentlandite, Eisennickelkies, $(\text{Fe}, \text{Ni})\text{S}$.

Cubic. Grains and granular masses. Octahedral cleavage. Hardness 3.5 to 4 and specific gravity 4.6 to 5.1. Metallic luster and usually light bronze-yellow in color. Streak black. Non-magnetic. Brittle and opaque. $(\text{Fe}, \text{Ni})\text{S}$. Yields easily on fusing a magnetic globule.

Occurs in large quantities at Sudbury, Ontario, in association with chalcopyrite and pyrrhotite. This is the source of most of the nickel used in the United States. Also in various localities in Norway, Sweden, Scotland, Australia, etc. There are no deposits of economic importance in the United States.

An important source of nickel. The output of the Sudbury, Ontario, region for 1906 was 21,490,000 pounds valued at \$8,948,834.

WURTZITE, Schalenblende, ZnS .

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 0.9353$. Crystals rare. Formed artificially. Consist of hexagonal prism with pyramid and basal pinacoid. Mostly as radial fibrous masses associated with sphalerite. Also compact massive. Prismatic and basal cleavages. Hardness 3.5 to 4. Specific gravity 3.98 to 4.07. Color dark brown. Streak light brown. Resinous luster.

ZnS , same as for sphalerite. Usually contains iron (up to 8%), also cadmium, sometimes as much as 3.66% (Mies, Bohemia). Easily soluble in cold concentrated hydrochloric acid while sphalerite is not.

Occurs generally in association with sphalerite. Not as common as sphalerite. Some of the important localities are Oruro, Bolivia; Příbram, Bohemia; Butte, Montana.

ERYTHROZINCITE, $(\text{Zn}, \text{Mn})\text{S}$, is a wurtzite containing manganese. Occurs at thick transparent plates in Siberian lapis lazuli.

Greenockite, CdS .

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 0.9364$. Natural crystals exceedingly small and rare. Usually show hexagonal prisms terminated on the one end with an hexagonal pyramid and on the other with a basal pinacoid. Pyramidal and tabular habits. Is usually found as an earthy coating.

Prismatic and basal cleavages. Hardness 3 to 3.5. Specific gravity 4.9 to 5. Honey, lemon, or orange yellow, also brown and brick red. Streak yellow. Resinous adamantine luster. Translucent.

CdS . Yields on charcoal or plaster tablet characteristic cadmium coating.

Not common. Usually with sphalerite and smithsonite. With sphalerite at Příbram, Bohemia, and many other European localities.

In the United States with the zinc ores in Missouri and Arkansas. Sometimes colors smithsonite a bright yellow.

Common as a furnace product.

PYRRHOTITE, Magnetic Pyrite, FeS.

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 0.9528$. Well developed crystals are not common. They usually show tabular development. Common type of occurrence is massive, often granular.

Basal cleavage but not usually observable. Brittle. Hardness 3.5 to 4. Specific gravity 4.54 to 4.64. Metallic luster. Opaque. Bronze-yellow to bronze-red in color. Tarnishes easily to a dark brown. Streak grayish black. Magnetic, sometimes only slightly.

Groth gives FeS as the probable composition of pyrrhotite. Analyses always show an excess of 1 to 2 and even more percent of sulphur, so that various formulae, varying from Fe_8S_8 to $\text{Fe}_{16}\text{S}_{17}$, are commonly given as indicating the composition of pyrrhotite. Fe_7S_8 and $\text{Fe}_{11}\text{S}_{12}$ are given most commonly. Rammelsberg suggested $\text{Fe}_n\text{S}_{n+1}$. Pyrrhotite sometimes contains small amounts of cobalt and nickel. Pyrrhotite containing much nickel is usually but slightly magnetic. Fuses on charcoal to a black magnetic mass. Decomposed by hydrochloric acid yielding hydrogen sulphide. Decomposes easily to pyrite, limonite, siderite, and arsenopyrite. Pseudomorphs of pyrite and arsenopyrite after pyrrhotite are rather common.

Usually found as a magmatic segregation in basic plutonic rocks such as gabbros, norites, and peridotites. Found also in schists and older eruptive rocks. It is commonly associated with pyrite, chalcopyrite, pentlandite, and galena. Occurs at Kongsberg, Norway; Falun, Sweden; Bodenmais, Bavaria; Andreasberg, Hartz Mountains; Joachimsthal, Bohemia, etc.

The most important localities in the United States are the Gap Mine, Lancaster Co., Pa., and Ducktown, Tenn.

Large deposits are found at Sudbury, Canada. Here pyrrhotite is associated with pyrite and chalcopyrite, and is nickeliferous.

Also found in meteorites in small quantities.

Pyrrhotite is an important source of nickel and cobalt.

Millerite, Capillary Pyrites, NiS.

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 0.9886$. Very fine, slender crystals. Often in radiated groups. Sometimes extremely fine and matted together like a wad or tuft of hair. Crystals are rarely doubly terminated. Also as a coating.



Basal and pyramidal cleavages. Hardness 3 to 3.5. Specific gravity 5.3 to 5.9. Metallic luster. Brass to bronze yellow in color. Sometimes shows a gray iridescent tarnish. Greenish black streak. Crystals are elastic.

NiS. Fuses to magnetic globule. Reacts for nickel and sulphur.

Never found in large quantities. Usually associated with nickel and cobalt minerals, also with hematite, calcite, dolomite, fluorite, pyrrhotite, chalcopyrite, etc. A few European localities are Joachimsthal, Bohemia, Příbram, Hungary; Freiberg district, Saxony, and Cornwall, England.

At Antwerp, N. Y., millerite occurs with hematite; at the Gap Mine, Lancaster Co., Pa., with pyrrhotite and chalcopyrite; at St. Louis, Mo., in limestone geodes with calcite, dolomite, and sphalerite.

Used to some extent as an ore of nickel.

Niccolite, Copper Nickel, Rothkupferkies, NiAs.

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 0.9462$. Crystals are rare. Usually massive and disseminated. Occasionally botryoidal and reniform.

Imperfect prismatic cleavage. Conchoidal to uneven fracture. Brittle. Hardness 5.5. Specific gravity 7.3 to 7.7. Metallic luster. Light copper red in color, tarnishes brown or grayish. As a result of decomposition niccolite is often coated with a green crust of annabergite, $Ni_3As_2O_8$, $8H_2O$. Streak brownish black.

NiAs, with small amounts of iron and cobalt. The arsenic is often replaced by varying percentages of antimony (up to 28%) and sulphur. Reacts for nickel and arsenic.

Commonly associated with nickel, cobalt, and silver ores, thus in the Freiberg district of Saxony; Joachimsthal, Bohemia; and the Cobalt district, Ontario. In the last named district niccolite occurs in large quantities, often in veins of considerable width. In smaller quantities at Chatham, Conn.; Franklin Furnace, N. J., Silver Cliff, Colo.; Thunder Bay, Lake Superior district; and Tilt Cove, New Foundland.

An important nickel ore.

ARITE is a niccolite containing a considerable amount of antimony and conforms to the formula $Ni(Sb,As)$. Not common.

BREITHAUPHITE, Antimonnickel, NiSb.

Hexagonal, ditrigonal pyramidal. $a : c = 1 : 0.9962$. Crystals are rare. Usually massive and disseminated. Basal cleavage. Uneven fracture. Brittle. Hardness 5. Specific gravity 7.5 to 7.6. Light copper red in color, on tarnishing shows a delicate violet shimmer. Reddish brown streak.

NiSb, with small percentages of iron. Fuses with difficulty.

Occurs with nickel ores, galena, and calcite at St. Andreasberg, Hartz Mountains; also at Sarrabus, Sardinia.

PYRITE—MARCASITE GROUPS

The metals iron, manganese, nickel, and cobalt form with two atoms of sulphur an interesting isodimorphous series of which the *pyrite* group crystallizes in the dyakisdodecahedral class of the cubic system, while the members of the *marcasite* group possess the symmetry of the orthorhombic bipyramidal class. The two groups of this series are:

PYRITE GROUP

(Cubic System)

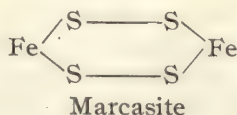
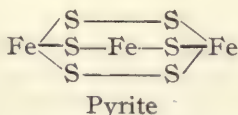
HAUERITE, MnS_2 .	Dyakisdodecahedral Class*
PYRITE, FeS_2.	Dyakisdodecahedral Class
Cobaltite, CoAsS.	Dyakisdodecahedral Class
GERSDORFFITE, NiAsS .	Dyakisdodecahedral Class
ULLMANNITE, NiSbS .	Dyakisdodecahedral Class
Smaltite, CoAs_2.	Dyakisdodecahedral Class
Chloanthite, NiAs_2.	Dyakisdodecahedral Class
SPERRYLLITE, PtAs_2 .	Dyakisdodecahedral Class

MARCASITE GROUP

(Orthorhombic System)

MARCASITE, FeS_2.	Bipyramidal Class	0.7662	:	I	:	1.2247
ARSENOPYRITE, FeAsS.	Bipyramidal Class	0.6775	:	I	:	1.1882
LÖLLINGITE, FeAs_2 .	Bipyramidal Class	0.6689	:	I	:	1.2331
GLAUCODOTE, $(\text{Co,Fe})\text{AsS}$.	Bipyramidal Class	0.6942	:	I	:	1.1925
SAFFLORITE, CoAs_2 .	Bipyramidal Class	0.6773	:	I	:	1.1882
WOLFACHITE, $\text{Ni}(\text{As, S, Sb})_2$.	Bipyramidal Class					?
RAMMELSBURGITE, NiAs_2 .	Bipyramidal Class					?

On account of the different chemical behavior of pyrite and marcasite there has been much speculation as to their chemical constitution. The following graphical formulae are often used to represent their respective constitutions.



The members of this series are comparatively hard, 5 to 6, and vary in color from brass yellow to tin white.

* Groth and others refer the members of this group to the tetrahedral pentagonal dodecahedral class.

HAUERITE, Mangankies, MnS_2 .

Cubic, *dyakisidodecahedral* class. Crystals show the octahedron, hexahedron, rhombic dodecahedron, pyritohedron ($m=2$), and *dyakisidodecahedron* ($n=3/2$, $m=3$). Octahedral and pyritohedral habits most common. Massive. Perfect cubical cleavage. Hardness 4. Specific gravity 3.4 to 3.5. When fresh, hauerite possesses metallic adamantine luster and brownish red color. But usually is dull, opaque, and brownish black. Reddish brown streak.

MnS_2 , sometimes contains iron. Reacts for manganese and sulphur. Decomposed by warm hydrochloric acid with an evolution of hydrogen sulphide and separation of sulphur.

Occurs in excellent isolated crystals in clay and gypsum at Kalinka, Hungary, and Raddusa, Sicily.

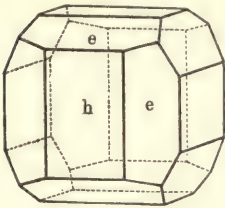


FIG. 15.

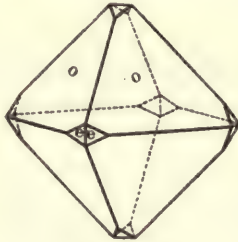


FIG. 16.

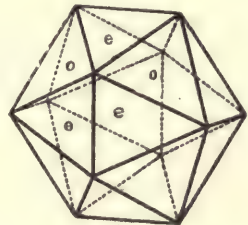


FIG. 17.

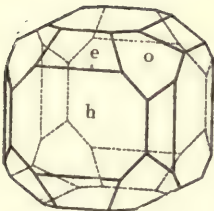


FIG. 18.

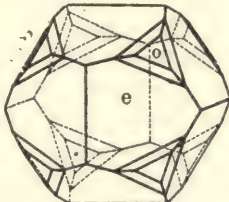


FIG. 19.

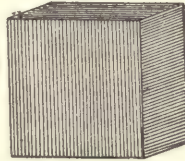


FIG. 20.

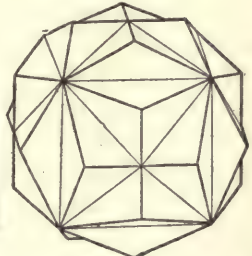


FIG. 21.

PYRITE, Fool's Gold, Iron Pyrites, FeS_2 .

Cubic, *dyakisidodecahedral* class. Crystals common and often very large. Over 100 forms have been observed. Among these the cube, octahedron, and pyritohedron ($m=2$) occur commonly as independent or predominating forms. Some of the common combinations are the cube and pyritohedron ($m=2$) Figure 15; octahedron and pyritohedron ($m=2$) Figures 16 and 17; cube, octahedron, and pyritohedron ($m=2$) Figure 18; also pyritohedron ($m=2$), octahedron, and *dyakisidodecahedron* ($n=3/2$, $m=3$) Figure 19. The crystal faces often show striations conforming to the symmetry of the *dyakisidodecahedral* class as shown by Figure 20. Interpenetration twins of pyritohedrons with the twinning plane parallel to a face of the rhombic dodecahedron, Figure 21, are sometimes called *crys-*

tals of the "iron cross." Crystals may be ideally developed but are often greatly distorted. Also massive and disseminated. Fine grained, granular, reniform, globular, stalactitic, also radiated.

Imperfect cubical cleavage. Conchoidal fracture. Hardness 6 to 6.5. Specific gravity 4.9 to 5.2, pure 5.18. Brittle. Metallic luster. Opaque. Pale brassy to golden yellow in color, sometimes with brown or variegated tarnish colors. Greenish to brownish black streak.

FeS_2 , with nickel, cobalt, copper, zinc, arsenic, gold, and silver in varying amounts. On charcoal yields sulphur dioxide and magnetic globule. Etched by aqua regia and potassium hydroxide. Insoluble in hydrochloric acid.

Decomposes readily, especially in a moist atmosphere. Limonite and goethite are the usual decomposition products, although various sulphates and sulphuric acid sometimes result. Pseudomorphs of limonite after pyrite are quite common.

Pyrite is the most common sulphide mineral and, hence, is found very widely distributed. It occurs in rocks of all ages. Its mode of occurrence varies greatly. Is usually associated with other sulphide minerals, such as galena, sphalerite, chalcopyrite, arsenopyrite, and the like. Also with calcite, siderite, hematite, magnetite, and so forth. Commonly found in quartz, often in association with native gold, see page 25. As nodules and concretions in many slates, sandstones, and coals.

Excellent crystals of pyrite are found in the Freiberg district, Saxony; Příbram, Bohemia; Schemnitz, Hungary, and elsewhere. Enormous quantities of massive gold and silver bearing pyrite occur at Rio Tinto, Spain.

In the United States especially fine crystals occur at Franklin Furnace, N. J.; Central City Mine, Gilpin Co., and elsewhere in Colorado; also French Creek, Pa. Large quantities of massive pyrite are annually obtained from Virginia, California, Massachusetts, New York, Alabama, Georgia, Ohio, Indiana, and South Dakota.

Pyrite is used principally as a source for sulphur dioxide in the manufacture of sulphuric acid by the chamber process, and also for sulphate of iron. Small quantities are also used as a mineral paint.

Cobaltite, Cobalt Glance, CoAsS .

Cubic, dyakisdodecahedral class. Usually as small, well developed, crystals showing either the cube or the pyritohedron ($m=2$). Sometimes both in combination. The cube faces are often striated as shown in Figure 20, page 39. More rarely in compact and granular masses.

Perfect cubic cleavage. Conchoidal to uneven fracture. Brittle. Hardness 5.5. Specific gravity 6 to 6.4. Fresh crystals show metallic luster. Opaque. Reddish silver white color. If cobaltite contains much iron the

color is apt to be gray. Often with a pinkish coating of erythrite, $\text{Co}_3\text{As}_2\text{O}_8 \cdot 8\text{H}_2\text{O}$. Grayish black streak.

CoAsS , usually with iron up to 12%. For the ferruginous variety the term *ferrocobaltite* is often used. Heated on charcoal cobaltite yields a garlic odor and a black magnetic globule. After roasting it gives a dark blue borax bead. Soluble in hot nitric acid.

An important cobalt mineral. Usually found in small quantities with other cobalt minerals, also with pyrrhotite, chalcopyrite, pyrite, galena, magnetite, and so forth. Occurs at Tunaberg and Håkansbo, Sweden; Skutterud and Nordmark, Norway; Westphalia, Germany; Cornwall, England; and the Cobalt district, Ontario.

GERSDORFFITE, Nickel Glance, NiAsS .

Cubic, dyakisdodecahedral class. Usually octahedral crystals. Other forms are the cube, dodecahedron, and pyritohedron ($m=2$). Crystals are rare. Compact and disseminated.

Rather perfect cubical cleavage. Uneven fracture. Brittle. Hardness 5.5. Specific gravity 5.2 to 6.2. Metallic luster. Opaque. Crystals are silver white to steel gray in color but on exposure tarnish dull dark gray. Sometimes coated green with annabergite, $\text{Ni}_3\text{As}_2\text{O}_8 \cdot 8\text{H}_2\text{O}$.

NiAsS , usually with 2 to 6% of iron. Cobalt may also be present. Garlic odor when heated on charcoal, also magnetic globule. Partially soluble in nitric acid yielding a green solution.

Not a common mineral. Usually alone or with ullmannite. In the Hartz Mountains; Sweden; Styria; Scotland; Ontario, Canada; British Columbia; and Phoenixville, Pa.

ULLMANNITE, Antimony—Nickel Glance, NiSbS .

Cubic, dyakisdodecahedral class. Sometimes referred to the tetrahedral pentagonal dodecahedral (tetartohedral) class. Most common forms are the cube, octahedron, and rhombic dodecahedron. Crystals are rare. Habit always cubic. Sometimes with pyritohedral and octahedral striations. Crystals from Lölling, Carinthia, show the tetartohedral development. Usually as compact, granular, disseminated masses.

Perfect cubic cleavage. Uneven fracture. Brittle. Hardness 5 to 5.5. Specific gravity 6.7 to 6.73. Opaque with metallic luster. Lead to steel gray, also dark gray color. Crystals are lighter in color than massive specimens. Does not decompose as readily as gersdorffite.

NiSbS , with iron and arsenic. On charcoal yields antimony coating and a metallic globule. Soluble in aqua regia yielding a green solution.

A rare mineral but more common than gersdorffite. Difficult to distinguish from gersdorffite by means of the physical properties only. Found at Lölling, Carinthia; Siegen, Westphalia; Hartz Mountains; and Montemarba near Sarrubus, Sardinia.

Smaltite, CoAs_2 .

Cubic, dyakisdodecahedral class. Crystals generally show a cubic habit but are not common. Usually observed in compact, granular, lamellar, or fibrous masses. Also reniform and reticulated.

No distinct cleavage. Uneven fracture. Brittle. Hardness 5.5. Specific gravity 6.4 to 6.6. Metallic luster and opaque. Crystals are tin white to light steel gray in color. Massive specimens are gray to dark gray. Tarnishes dull and is often coated with erythrite (pink) or pharmacolite (white). Streak grayish black. When struck with a hammer yields garlic odor. Difficult to distinguish from chloanthite by means of the physical properties only.

CoAs_2 , usually with varying amounts of nickel, iron, and sulphur. The iron content sometimes amounts to 18% which causes an increase in the specific gravity. On charcoal smaltite yields a garlic odor and grayish black magnetic globule. Easily soluble in nitric acid yielding a green solution.

The most common cobalt mineral. Always with cobalt, nickel, and silver ores, also with native bismuth, barite, siderite, quartz, arsenopyrite and so forth. Thus in the Freiberg district, Saxony; Cornwall, England; Joachimsthal, Bohemia; Dobschau, Hungary; Tunaberg, Sweden; La Motte Mine, Mo.; and Cobalt district, Ontario.

Smaltite is an important ore of cobalt.

Chloanthite, NiAs_2 .

This mineral is very similar to smaltite in all its crystallographic, physical, and chemical properties. Contains, however, more nickel than smaltite and, hence, is often covered with a green coating of annabergite. A variety from Chatham, Conn., containing 12% of iron and 5% of sulphur, is known as *chathamite*.

Occurrence same as for smaltite from which it sometimes cannot be distinguished without a chemical analysis.

Important nickel ore.

SPERRYLITE, PtAs_2 .

Cubic, dyakisidodecahedral class. Small cubic crystals. The cube, octahedron, and pyritohedron ($m=2$) are the common forms. Hardness 6 to 7. Specific gravity 10.6. Looks like platinum. Metallic luster. Streak black.

PtAs_2 , but contains small amounts of rhodium, iron, and antimony.

Occurs in the Sudbury district, Ontario; Rambler Mine, Wyoming; also in the stream beds of Macon Co., North Carolina.

The only compound of platinum occurring in nature.

MARCASITE, White Iron Pyrites, Spear Pyrites, FeS_2 .

Orthorhombic, bipyramidal class. $a : b : c = 0.7662 : 1 : 1.2347$. Crystals are usually tabular or short columnar. The commonly observed forms are the basal pinacoid, unit prism, the unit and modified ($m=1/3 c$) brachydomes. Twins are very common. Two twinning laws are to be noted with the twinning planes parallel to the unit prism and merodome. Cyclic and polysynthetic twins according to the first law are rather common.

Also massive, stalactitic, reniform, and globular. Often with radial structure.

Indistinct prismatic cleavage. Uneven fracture. Brittle. Opaque. Metallic luster. Hardness 6 to 6.5. Specific gravity 4.65 to 4.88 (*pyrite* 4.9 to 5.2). Pale brass yellow or steel gray in color; darker after exposure. Usually lighter in color than pyrite. Streak greenish gray.

FeS_2 , contains at times copper and arsenic. Chemical properties as for pyrite. However, marcasite decomposes more readily than pyrite. Marcasite dissolves in concentrated nitric acid with separation of sulphur while pyrite does not.

Very abundant but not so much so as pyrite. When massive, difficult to distinguish from pyrite. Occurs often with pyrite, galena, fluorite, and sphalerite. Common as concretions in marls, clays, limestones, and coals. In lignite at Littnitz and Altsattel, Bohemia; in marl at Folkestone, England; in limestone at Limmer near Hannover, Germany; with galena and fluorite Derbyshire, England.

In the United States at Galena, Ill., in stalactites; with sphalerite and galena, Mineral Point, Wis.; with sphalerite, calcite, etc., at Joplin, Mo. Abundant in many sedimentary rocks especially those containing organic matter; also common in coal.

Uses same as for pyrite.

ARSENOPYRITE, Mispickel, FeAsS .

Orthorhombic, bipyramidal class. $a : b : c = 0.6775 : 1 : 1.1882$. The axial ratio varies with the chemical composition. Often in disseminated crystals which may be long or short prismatic. The usual combination consists of the unit prism and a modified brachydome ($m = 1/4 c$) which are often so developed as to simulate an octahedron. The unit brachy and macrodomes are also frequently observed. The brachydomes are often striated parallel to the a axis. Also often as twins. Most commonly as penetration twins with the unit macrodome as the twinning plane. A second twinning law, with a face of the unit prism as the twinning plane, is less common. Twins according to second law may be either contact or penetration twins. Arsenopyrite also occurs in columnar, radial, or granular masses; compact and disseminated; reticulated.

Distinct prismatic cleavage. Uneven fracture. Brittle. Hardness 5.5 to 6. Specific gravity 5.9 to 6.2. Color is silver white to a light steel gray, tarnishing to brass yellow or gray. Streak black. Opaque. Metallic luster.

FeAsS , often containing cobalt, antimony, bismuth, silver, and gold. The amount of arsenic varies considerably so that analyses do not always conform to the composition given. Arsenopyrite is sometimes considered

as an isomorphous mixture of marcasite FeS_2 and löllingite FeAs_2 in varying proportions. The variety containing 3 to 9% of cobalt replacing iron is called *danaite*. On charcoal gives garlic odor and black magnetic globule. Soluble in nitric acid with separation of sulphur.

Commonly associated with the ores of tin, nickel, cobalt, silver, gold, and lead, also with pyrite, chalcopyrite, and sphalerite. Found in the Freiberg district, Saxony; in serpentine at Reichenstein, Silesia; Cornwall, England; Tunaberg, Sweden; Skutterud, Norway; in dolomite in Binnenthal, Switzerland, and elsewhere.

In the United States at Franconia, N. H.; Chatham, Conn.; Nevada Co., California; Floyd and Montgomery counties, Virginia; various places in Washington. Also at Deloro, Ontario, in gold bearing quartz veins.

Arsenopyrite is used principally for the manufacture of arsenic trioxide, the arsenic of commerce. If present in sufficient quantities, gold, silver, and cobalt are extracted. Arsenopyrite is mined in Washington and in Floyd and Montgomery counties, Virginia.

LÖLLINGITE, Leucopyrite, FeAs_2 .

Orthorhombic, bipyramidal class. $a : b : c = 0.6689 : 1 : 1.2331$. Crystals are rare and small. Usual combination consists of the unit prism and the unit macrodome. Mostly compact and in disseminated granular and acicular aggregates.

Distinct basal cleavage. Uneven fracture. Brittle. Hardness 5 to 5.5. Specific gravity 7.1 to 7.4. Opaque. Metallic luster. Silver white in color, tarnishes gray. Gray black streak.

FeAs_2 , always contains sulphur up to 6%. Cobalt, nickel, gold, bismuth, and antimony may also be present. The arsenic content varies considerably. When the composition approaches Fe_2As_3 , the term *leucopyrite* is often used. Yields on charcoal the garlic odor of arsenic and fuses with difficulty to a black non-magnetic globule.

Not a common mineral. In serpentine, sometimes auriferous, at Reichenstein, Silesia; with siderite at Lölling near Hüttenberg, Carinthia; Andreasberg, Hartz Mountains; Roxbury, Conn.; Brush Creek, Gunnison Co., Colorado.

GLAUCODOTE, $(\text{Co}, \text{Fe})\text{AsS}$.

Orthorhombic, bipyramidal class. Occurs in tin white crystals of a prismatic habit showing a basal cleavage. Also massive. Hardness 5. Specific gravity 5.9 to 6.01. Metallic luster. Contains 16 to 25% of cobalt and 12 to 19% of iron. Hintze considers *danaite*, page 44, as a variety of glaucodote. Is found in crystals of considerable size in the chlorite schists of Hakansbo, Sweden, and Huasco, Chile.

SAFFLORITE, Spathiopyrite, CoAs_2 .

Orthorhombic, bipyramidal class. This is the orthorhombic modification of CoAs_2 . Small crystals similar to those of arsenopyrite. Also compact, radial, and fibrous masses. Tin white in color but tarnishes rapidly to gray. Hardness 4 to 5. Specific gravity 6.9 to 7.3. Opaque. Streak gray black. Schneeberg, Saxony; Bieber, Hesse; Wittichen, Baden; Tunaberg and Nordmarken, Sweden; Badeni-Ungureni, Roumania.

WOLFACHITE, $\text{Ni}(\text{As, Sb})_2$.

Orthorhombic. Very small crystals similar to arsenopyrite, also in radial aggregates. Opaque. Metallic luster. Silver white to tin white in color. Streak black. Brittle. Hardness 4 to 5. Specific gravity 6.372. Occurs as a crystallized coating on niccolite associated with calcite, galena, and dyscrasite at Wolfsbach, Baden.

RAMMELSBURGITE, NiAs_2 .

Orthorhombic modification of NiAs_2 . Small crystals similar to arsenopyrite. Also compact, granular to fine columnar and fibrous masses. Metallic luster. Opaque. On fresh fracture surface color is tin white with tinge of red. Streak gray black. Prismatic cleavage. Hardness 5 to 6. Specific gravity 7.1 to 7.19. Occurs in limited quantities associated with chloanthite at Schneeberg, Saxony; Reichelsdorf, Hesse; Lölling-Hüttenberg, Carinthia.

SKUTTERUDITE, CoAs_3 .

Cubic, dyakisdodecahedral class. Crystals show the octahedron, tetragonal tris-octahedron ($m=2$), rhombic dodecahedron, pyritohedron ($m=3$), and dyakisdodecahedron ($n=3/2$, $m=3$). Also massive. Distinct cubical cleavage. Conchoidal to uneven fracture. Brittle. Hardness 6. Specific gravity 6.48 to 6.86. Metallic luster. Light steel gray to tin or greenish white. Tarnishes somewhat reddish. Black streak. Contains small amounts of iron. Found associated with cobaltite in mica schists at Skutterud, Norway.

WHITNEYITE, Cu_9As .

Crystal form unknown. Fine grained; reddish white in color with brownish and black tarnish colors. Specific gravity 8.47. Hardness 3. Malleable. Metallic luster. Houghton Co., Mich.; Sonora, Mexico.

ALGODONITE, Cu_6As .

Crystal form unknown. Massive. Silver white to steel gray. Hardness 4. Specific gravity 6.9 to 7.6. Resembles domeykite. Occurs at Algodona, near Coquimbo, Chile; Lake Superior Copper district.

DYSCRASITE GROUP

The basic arsenides and antimonides of copper and silver apparently form an isomorphous group, as shown by a comparison of their ratios.

	a	:	b	:	c
DOMEYKITE, Cu_8As . Orthorhombic Bipyramidal Class	0.5771	:	1	:	0.6802
Dyscrasite, Ag_8Sb. Orthorhombic Bipyramidal Class	0.5775	:	1	:	0.6718

The elements of crystallization given for domeykite are for artificial crystals.

DOMEYKITE, Cu_3As .

Natural crystals unknown. Compact, reniform, botryoidal, and disseminated masses. Tin white in color with yellow and variegated tarnish colors. Hardness 3.5. Specific gravity 7.2 to 7.5. Brittle. Easily fusible. Occurs in Chile; Mexico; with niccolite on Michipicoten Island, Lake Superior; and in the Lake Superior Copper district.

A variety of domeykite containing about 10% of nickel and cobalt occurs at the Mohawk Copper mine, Lake Superior district, and is termed *mohawkite*.

Dyscrasite, Ag_3Sb . (?)

Orthorhombic, bipyramidal class. $a : b : c = 0.5775 : 1 : 0.6718$. Crystals rarely well developed. Usually columnar, pyramidal, or tabular in habit. Unit prism, brachy and basal pinacoids, unit and modified bipyramids are among the forms observed. Striations parallel to the a axis on the basal pinacoid. Repeated twinning parallel to the unit prism, hence often pseudohexagonal. Also compact, granular, nodular, and as a coating.

Perfect brachydomatic cleavage. Brittle. Uneven fracture. Hardness 3.5. Specific gravity 9.4 to 10. Silver white, tarnishes gray, black, or yellow brown.

Ag_3Sb ; composition varies greatly, so that formulae ranging from Ag_{18}Sb to Ag_3Sb have been assigned to dyscrasite. Easily fusible on charcoal yielding the antimony coating and a globule of silver.

Occurs associated with silver, antimony, arsenic, and cobalt minerals. Thus, at Andreasberg, Hartz Mountains; Allemont, France; Spain; Peru; Chile; Cobalt district, Ontario.

Valuable silver ore.

GALENA—CHALCOCITE GROUPS

The monosulphides and so forth of lead, silver, and copper form an isodimorphous series which embraces the cubic—*galena*—and orthorhombic—*chalcocite*—groups. Silver sulphide is the only compound occurring in both groups.

GALENA GROUP*(Cubic System)***GALENA, PbS .**CLAUSTHALITE, PbSe .ALTAITE, PbTe .**Argentite, Ag_2S .**JALPAITE, $(\text{Ag,Cu})_2\text{S}$.AGUILARITE, $\text{Ag}_2(\text{S, Se})$.NAUMANNITE, $(\text{Ag}_2, \text{Pb})\text{Se}$.EUCAIRITE, $(\text{Ag, Cu})_2\text{Se}$.HESSITE, Ag_2Te .

Hexoctahedral Class

Hexoctahedral Class

Hexoctahedral Class

Hexoctahedral Class

Hexoctahedral Class

Hexoctahedral Class

Hexoctahedral Class

Hexoctahedral Class

Hexoctahedral Class

CHALCOCITE GROUP*(Orthorhombic System)*

	<i>a</i>	: <i>b</i>	: <i>c</i>
CHALCOCITE , Cu_2S . Bipyramidal Class	0.5882	: 1	: 0.9702
Stromeyerite , $(\text{Cu}, \text{Ag})_2\text{S}$. Bipyramidal Class	0.5822	: 1	: 0.9668
ACANTHITE , Ag_2S . Bipyramidal Class	0.6886	: 1	: 0.9945
PETZITE , $(\text{Ag}, \text{Au})_2\text{Te}$. Bipyramidal Class			?

The members of the chalcocite group crystallize in forms with a prism angle of approximately 120° and, hence, are more or less pseudohexagonal.

GALENA, Galenite, Lead Glance, **PbS**.

Cubic, hexoctahedral class. Well developed crystals are rather common. Cube and octahedron, either independently or in combination, Figures 22 and 23; also the rhombic dodecahedron, Figures 24 and 25; and the

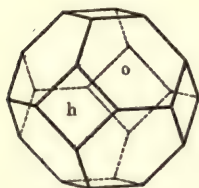


FIG. 22.

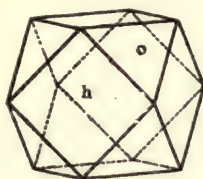


FIG. 23.

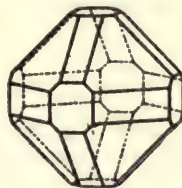


FIG. 24.

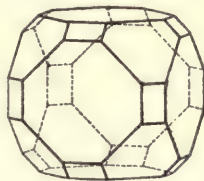


FIG. 25.

tetragonal ($m=3$, $m=2$) and trigonal ($m=2$) trisoctahedrons are the forms most commonly observed. Penetration twins with twinning plane parallel to a face of the octahedron. Also skeletal crystals; reticulated, and tabular. Mostly in cleavable masses. Compact, granular, fine grained; rarely stalactitic and fibrous.

Very perfect cubical cleavage. Hardness 2.5. Specific gravity 7.3 to 7.6. Metallic luster, especially on cleavage surfaces; otherwise rather dull. Lead gray in color. Grayish black streak.

PbS, often with small amounts of silver, antimony, iron, zinc, gold, or bismuth. The amount of silver present is generally rather low, 0.05 to 0.3%, sometimes, however, 1% or more. On this account galena is an important silver ore. The silver content can be detected only by assay. Reacts for lead and sulphur. Soluble in nitric acid with separation of sulphur and lead sulphate.

Very abundant. Usual associates are sphalerite, chalcopyrite, quartz,

pyrite, calcite, barite, fluorite, marcasite, arsenopyrite, anglesite, cerussite, pyromorphite, etc.

Galena may occur in general in two ways: (1) *In veins* with pyrite, chalcopyrite, sphalerite, barite, calcite, quartz or fluorite, and (2) *in cavities* in dolomitic limestones associated with calcite, sphalerite, smithsonite, etc. Galena of the first type of occurrence is usually argentiferous.

Only a few of the most important localities will be indicated, namely, Freiberg district, Saxony; Clausthal, Hartz Mountains; Příbram and Joachimsthal, Bohemia; Derbyshire, Cumberland; Mexico; Chile; Bolivia; Australia.

In the United States extensive deposits are found in the limestones of Wisconsin, Illinois, Missouri, Iowa, and Kansas. Excellent crystals occur at Mineral Point, Wis.; Joplin, Mo., and elsewhere. The argentiferous variety is common in the Leadville, Aspen, Silverton, and other districts of Colorado; also in Utah, Montana, Idaho, etc.

A valuable lead and silver ore. In 1908 the United States produced 310,762 tons of lead, obtained mostly from galena.

CLAUSTHALITE, PbSe .

Cubic, hexoctahedral class. Rarely in cubes. Commonly in fine grained masses. Sometimes foliated. Looks like galena. Hardness 2.5 to 3. Specific gravity 7.6 to 8.8. May contain silver or cobalt in small amounts. Occurs at Clausthal, Lerbach, Zorge, and Tilkerode in the Hartz Mountains; Cacheuta, Argentine Republic.

ALTAITE, PbTe .

Cubic, hexoctahedral class. Sometimes in cubes, usually in fine grained masses. Metallic luster. Color tin white to yellow, tarnishes bronze yellow. Indistinct cubical cleavage. Uneven to conchoidal fracture. Hardness 3 to 3.5. Specific gravity 8.1 to 8.2. May contain a little silver. With hessite at Altai; Coquimbo, Chile; Red Cloud Mine, Colorado; Calaveras Co., California.

Argentite, Silver Glance, Ag_2S .

Cubic, hexoctahedral class. Crystals may be cubical, octahedral, or rhombic dodecahedral in habit. All forms of the hexoctahedral class have been observed. Penetration twins with the twinning plane parallel to a face of the octahedron. Parallel grouping. Massive and disseminated. Filiform and as a coating.

Indistinct cubical and rhombic dodecahedral cleavages, rarely observed. Small conchoidal fracture, not very distinct. Malleable, sectile; takes impression. Hardness 2 to 2.5. Specific gravity 7.2 to 7.4. On fresh surface high metallic luster, but on exposure soon becomes dull and black. Dark lead gray in color. Shiny streak.

Ag_2S . On charcoal fuses with intumescence yielding fumes of sulphur dioxide and a globule of silver.

Commonly associated with silver, cobalt, and nickel minerals. Occurs at Freiberg, Saxony; Joachimsthal, Bohemia; Schemnitz, Hungary; Kongsberg, Norway; Cornwall, England; Guanajuata, Mexico; Peru; Chile; etc. Also at the Comstock Lode, Nevada; with silver and copper in the Lake Superior Copper district; in comparatively large amounts in the Cobalt district, Ontario.

An important ore of silver.

JALPAITE, $(\text{Ag}, \text{Cu})_2\text{S}$, is a cupriferous argentite. Sectile. Dark lead gray in color. Occurs at Jalpa, Mexico; also in Chile.

AGUILARITE, $\text{Ag}_2(\text{S}, \text{Se})$. An argenite containing selenium. Black skeletal rhombic dodecahedrons. Also as fine needles. Sectile. Specific gravity 7.59. Occurs at Guanajuata, Mexico.

NAUMANNITE, $(\text{Ag}_2, \text{Pb})\text{Se}$. Cubic crystals. Usually compact with cubical cleavage. Sectile. Metallic luster. Hardness 2.5. Specific gravity 8. Iron black in color and streak. With clausthalite at Tilkerode, Hartz Mountains.

EUCAIRITE, $(\text{Ag}, \text{Cu})_2\text{Se}$. Fine grained and massive. Indistinct cubical cleavage. Hardness 2 to 3. Specific gravity 7.67. Metallic luster. Tin white to gray. In serpentine at the Skrikerum Copper mine, Sweden; Copiapó, Chile; Sierra de Umango, Argentine Republic.

HESSITE, Ag_2Te .

Cubic, hexoctahedral class. Cubical crystals, often greatly distorted and highly modified. Coarse and fine grained, compact masses. Sectile. Hardness 2.5. Specific gravity 8.3 to 9. Lead gray. At times contains gold and lead. Transylvania; Altai; Hungary; Chile; Calaveras Co., California; Boulder Co., Colorado; Utah; Arizona.

CHALCOCITE, Copper Glance, Cu_2S .

Orthorhombic, bipyramidal class. $a : b : c = 0.5882 : 1 : 0.9702$. Crystals are usually thick tabular or short prismatic. Pseudo-hexagonal on account of prism angle being $119^\circ 35'$. A common combination consists of the basal pinacoid c , the brachydome $(m=2/3)e$, and the modified bipyramid $(m=1/3)z$, Figure 26. A comparatively large number of forms has

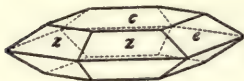


FIG. 26.

been observed. Basal pinacoid is often striated parallel to the a axis. Several twinning laws. Twinning plane parallel to unit prism most common. Trillings according to this law are pseudo-hexagonal in form. Also star-shaped forms. Usually compact and disseminated masses; granular.

Indistinct prismatic cleavage. Conchoidal to uneven fracture. Hardness 2.5 to 3. Specific gravity 5.5 to 5.8. High metallic luster on fresh surface which soon becomes dull and black. Color dark lead gray, often tarnished blue or greenish. Streak shiny lead gray.

Cu_2S , usually with iron, also gold and silver. Soluble in nitric acid with separation of sulphur and formation of green solution. Decomposes readily to chalcopyrite, bornite, covellite, malachite, and azurite.

Usual associates are chalcopyrite, bornite, tetrahedrite, siderite, cassiterite, malachite, and azurite. Chalcocite may occur, first, *in veins* and second, as *an impregnation*, especially in bituminous sedimentary rocks. Occurs in veins at Cornwall, England, (excellent crystals); Freiberg, Saxony; Joachimsthal, Bohemia; Kapnik, Transylvania; Bristol, Conn.; Butte Copper district, Montana; Nevada; Arizona; Sonora, Mexico; Province of Quebec. As an impregnation at Mansfield, Germany.

Chalcocite is an important ore of copper.

Stromeyerite, Copper Silver Glance, $(\text{Cu}, \text{Ag})_2\text{S}$.

Orthorhombic, bipyramidal class. Crystals like chalcocite. Usually massive and disseminated. Hardness 2.5 to 3. Specific gravity 6.2 to 6.3. Conchoidal fracture. Metallic luster. Dark lead gray in color and streak. Difficult to distinguish from chalcocite. Reacts for copper, silver, and sulphur.

Not abundant. Associated with copper and silver minerals. Thus at various places in Siberia, Argentine Republic, Chile, Mexico, Arizona, and Colorado. In considerable quantities in the Cobalt district, Ontario.

A valuable silver ore.

ACANTHITE, Ag_2S . Orthorhombic modification of Ag_2S . Peculiarly twisted, bent, and distorted crystals. Physical and chemical properties like argentite. Found at Joachimsthal, Bohemia; Freiberg, Saxony; etc. According to Krenner acanthite is argentite occurring in misshapen crystals.

PETZITE, $(\text{Ag}, \text{Au})_2\text{Te}$. Usually massive, granular to compact. Lead gray to iron black color. Black streak. Brittle. Much like hessite, page 49. Hardness 2.5 to 3. Specific gravity 8.7 to 9.4. Nagyág, Transylvania; Calaveras and Tuolumne Counties, California; Red Cloud Mine, Colorado, etc.

CINNABAR GROUP

This is an isodimorphous group and embraces the sulphides and selenides of copper and mercury. One series crystallizes in the cubic, the other in the hexagonal system.

METACINNABAR SERIES

(Cubic System)

METACINNABARITE, HgS .

Hextetrahedral Class

ONOFRITE, $\text{Hg}(\text{S}, \text{Se})$.

Hextetrahedral Class

TIEMANNITE, HgSe .

Hextetrahedral Class

CINNABAR SERIES

(Hexagonal System) $a : c$ **Covellite, CuS.** Trigonal Trapezohedral Class I : 1.1455**CINNABAR, HgS.** Trigonal Trapezohedral Class I : 1.1453

The members of the metacinnabar series are of little economic importance.

METACINNABARITE, HgS. Cubic, hextetrahedral class. Small crystals with positive and negative tetrahedrons about equally developed. Rare. Usually massive, also as an apparently amorphous powder and coating. Hardness 3. Specific gravity 7.7 to 7.8. Iron black with black streak. Chemical composition like cinnabar. Occurs with cinnabar at various places, especially at Reddington Mine, Lake Co., California.

ONOFRITE, Hg(S,Se). Massive, fine grained Conchoidal fracture. Hardness 2 to 3. Specific gravity 7.6 to 8.1. Color and streak gray black. According to Brush and Penfield onofrite is an isomorphous mixture of metacinnabar and tiemannite. Occurs at San Onofre, Mexico; in considerable quantities at Marysville, Utah.

TIEMANNITE, HgSe. Cubic, hextetrahedral class. Crystals usually with tetrahedral habit. Sometimes highly modified. Usually massive, granular to compact. Metallic luster. Steel gray to black lead gray color. Streak nearly black. Hardness 2 to 3. Specific gravity 7.1 to 8.5. In closed tube yields a black sublimate, at a distance it appears brown. Soluble only in aqua regia. With hematite at Clausthal, Tilkeroode, and Zorge in the Hartz Mountains; Clear Lake, Cal.; Marysvale, Piute Co., Utah.

Covellite, CuS.

Hexagonal, trigonal trapezohedral class. $a : c = 1 : 1.1455$. Crystals thin tabular, rare. Usually in compact, fine grained masses. Also as a coating and crust; in veinlets, reniform, and powdery.

Perfect basal cleavage. Compact specimens possess an even fracture. Thin plates are flexible. Hardness 1 to 2. Specific gravity 4.59 to 4.64. Blue black color, when rubbed, indigo blue. Streak black. Dull luster. when rubbed, submetallic and resinous.

CuS, may contain lead and iron. Easily fusible. Colors flame blue. Soluble in nitric acid with separation of sulphur.

Usually with chalcopyrite, bornite, or chalcocite from the decomposition of which it has resulted. Occurs in Chile; Bolivia; especially in the Butte Copper district, Montana; Rambler Mine, Wyoming; in veins on Kawan Island near New Zealand; as a sublimation product on Mount Vesuvius.

Of minor importance, commercially, as an ore of copper.

CINNABAR, Natural Vermilion, HgS .

Hexagonal, trigonal trapezohedral class. $a : c = 1 : 1.1453$. Extremely small but highly complex crystals. Over 100 forms have been observed. Crystals are usually rhombohedral or thick tabular in habit, Figure 27. The trigonal trapezohedrons are rarely observed. Two twinning laws are common; first, vertical axis is the twinning axis and, second, hexagonal prism of the second order acts as twinning plane. Usually in fine grained, granular masses; also as crystalline crusts or powdery coating.

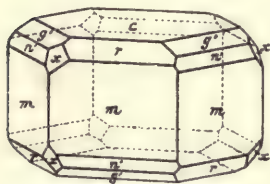


FIG. 27.

Perfect prismatic cleavage. Uneven, splintery, or subconchoidal fracture. Hardness 2 to 2.5. Specific gravity 8 to 8.2. Adamantine luster. In thin plates transparent, otherwise opaque. Color and streak cochineal red. The color may, however, on account of impurities and structural differences be scarlet or brownish red, also brown, black, or lead gray. Slightly sectile. Positive double refraction. High indices of refraction, $n_r = 2.854$, $n_e = 3.201$. Strong circular polarization, fifteen times that of quartz.

HgS , may contain bitumen, clay, ferric oxide, and so forth as impurities. Easily volatile. Soluble only in aqua regia.

Cinnabar is found in veins, disseminated or irregular masses, in sedimentary rocks of various ages as also in trachytes, quartz porphyries, and serpentine. The common associates are native mercury, pyrite, marcasite, chalcopyrite, stibnite, bitumen, realgar, gold, calcite, barite, fluorite, quartz, and opal.

Occurs in silurian sandstone at Almaden, Spain; in triassic shales and dolomite at Idria, Carniola; Moschellandsberg and elsewhere in the Palatinate, west of the Rhine; also in Chile, Peru, Mexico, Japan, and China.

In the United States the principal deposits are at New Almaden, Santa Clara Co., also Altoona; Trinity Co., and New Idria, San Benito Co., California. These deposits are mostly associated with serpentine. The Terlingua district, Texas, is also a producing locality. Here cinnabar is found in rocks of cretaceous age and is associated with native mercury, calcite, hematite, limonite, and sometimes pyrite.

At the Steamboat Springs, Nevada, cinnabar is still being deposited, as is also the case at the Sulphur Bank Mine, California.

According to G. F. Becker cinnabar has been precipitated principally from ascending waters. The mercury is supposed to have been in solution as a double sulphide and then deposited as cinnabar by the action of bituminous matter.

Cinnabar is the chief source of metallic mercury which is used extensively in commerce, see page 24. In 1906 the United States produced 28,293 flasks of mercury, each weighing $76\frac{1}{2}$ lbs. Of this production, 22,500 flasks were from California and 4,517 flasks from Texas. The remainder was obtained from Arizona, Oregon, Utah, and Washington. In 1906 mercury sold at about \$39.00 per flask.

SYLVANITE GROUP

Here are placed four tellurides of gold and silver. Nothing definite can be said as yet with respect to their chemical or crystallographic relationships.

	<i>a</i>	<i>b</i>	<i>c</i>
Sylvanite, (Au,Ag)Te₂. Monoclinic Prismatic Class	1.6339	1	1.1265, $\beta=90^{\circ}25'$
Calaverite, AuTe₂. Monoclinic Prismatic Class	1.6313	1	1.1449, $\beta=90^{\circ}13'$
KRENNERITE, (Au,Ag)Te₂. Orthorhombic Bipyramidal Class	0.9389	1	0.5059
NAGYAGITE, Au₂Sb₂Pb₁₀Te₆S₁₅. Orthorhombic Bipyramidal Class	0.2807	1	0.2761

Although of not very common occurrence, they are, especially sylvanite and calaverite, of great importance as gold ores.

Sylvanite, Graphic Tellurium, (Au,Ag)Te₂.

Monoclinic, prismatic class. $a : b : c = 1.6339 : 1 : 1.1265$, $\beta=90^{\circ}25'$. Crystals are very small but at times highly complex. Sometimes tabular, prismatic, or pseudo-orthorhombic in habit. Occurs also in branching arborescent forms simulating written characters. Twinning is common parallel to the orthodome. Skeletal development of crystals. Bladed, and imperfect columnar to granular aggregates. Compact granular aggregates are rare.

Perfect clinopinacoidal cleavage. Hardness 1.5 to 2. Specific gravity 7.99 to 8.33. Metallic luster. Steel gray to silver white, also light yellow in color. Streak same as color.

(Au,Ag)Te₂, containing also antimony, lead and copper. The gold and silver are usually present in the following proportion: Au : Ag = 1 : 1. Easily fusible. On charcoal yields a white coating. With soda gives a metallic silver-gold globule.

An important ore of gold. Occurs at Offenbánya and Nagyág, Transylvania; Calaveras Co., Cal.; Red Cloud Mine, and the Cripple Creek district, Colorado.

Calaverite, AuTe_2 .

Monoclinic, prismatic class. $a : b : c = 1.6313 : 1 : 1.1449$, $\beta = 90^\circ 13'$. Not well crystallized. Has been considered triclinic. Angles similar to those of sylvanite. Crystals are rare. Usually compact. Conchoidal fracture. No cleavage. Hardness 2.5. Specific gravity 9. Metallic luster. Bronze yellow in color.

AuTe_2 . Essentially a telluride of gold with varying amounts, up to about 4%, of silver.

Found at Stanislaus Mine, Calaveras Co., California; Red Cloud Mine and Cripple Creek district, Colorado; Western Australia.

An ore of gold.

KRENNERITE, $(\text{Au}, \text{Ag})\text{Te}_2$. Orthorhombic, bipyramidal class. $a : b : c = 0.9389 : 1 : 0.5059$. Crystals are small, columnar, and vertically striated. Hardness 2 to 3. Specific gravity 8.35. Metallic luster. Silver white to light brassy yellow in color. Like sylvanite in composition. Occurs in quartz at Nagyág, Transylvania; Cripple Creek district, Colorado; and Western Australia. Not as abundant as sylvanite or calaverite.

NAGYAGITE, $\text{Au}_2\text{Sb}_2\text{Pb}_{10}\text{Te}_6\text{S}_{15}$.

Orthorhombic, bipyramidal class. $a : b : c = 0.2807 : 1 : 0.2761$. Tabular crystals, with brachypinacoid predominating. Granular massive and foliated. Excellent clinopinacoidal cleavage. Flexible. Hardness 1 to 1.5. Specific gravity 6.7 to 7.2. Metallic luster. Dark lead gray in color. Gray black streak inclining to brown.

$\text{Au}_2\text{Sb}_2\text{Pb}_{10}\text{Te}_6\text{S}_{15}$, may contain copper. Composition is not constant.

Occurs at Nagyág and Offenbánya in Transylvania; also in various places in Colorado associated with sylvanite.

An ore of gold.

3. SULPHO-SALTS

Here are placed those minerals which can be referred to the sulpho acids H_3FeS_3 , H_3AsS_3 , H_3SbS_3 and the like, or to acids derived from them.

CHALCOPYRITE GROUP

This group contains the copper salts of the following sulpho acids of iron: H_3FeS_3 , HFeS_2 , and $\text{H}_4\text{Fe}_2\text{S}_5$. The meta acid, HFeS_2 , can be conceived as being derived from one molecule of the ortho acid, H_3FeS_3 , by the elimination of a molecule of H_2S . Two molecules of H_3FeS_3 with the elimination of a molecule of H_2S would yield the pyro acid, $\text{H}_4\text{Fe}_2\text{S}_5$.

The group consists of:

BORNITE, Cu_3FeS_3 .

Cubic, Hexoctahedral Class

CHALCOPYRITE, CuFeS_2 .

Tetragonal, Scalenohedral Class

BARNHARDTITE, $\text{Cu}_4\text{Fe}_2\text{S}_5$.

?

Barnhardtite is an exceedingly rare mineral and is only of scientific interest.

BORNITE, Purple Copper Ore, Variegated Copper Ore, Horse Flesh Ore,
 Cu_3FeS_3 .

Cubic, hexoctahedral class. Crystals not common. Cube, either alone or in combination with the octahedron, is the usual form. The rhombic dodecahedron and tetragonal trisoctahedron ($m=2$) are also observed. Twins parallel to the octahedron. Usually occurs as compact, granular masses.

Conchoidal to uneven fracture. Hardness 3. Specific gravity 4.9 to 5.1. Metallic luster. Color on fresh fracture surface is between bronze brown and copper red. Tarnishes readily to deep blue purple tints. Streak gray black.

Cu_3FeS_3 , the composition often varies, due to admixture of Cu_2S . May also contain silver and gold in small amounts. Fuses to gray metallic globule. Soluble in nitric and concentrated hydrochloric acids with a separation of sulphur.

Occurs with chalcopyrite, chalcocite, and other copper minerals, also with cassiterite and siderite. Is not very common in Europe. Found at Cornwall, England; Freiberg district, Saxony; Mansfield, Germany; Hartz Mountains; Tuscany; Siberia; Norway; Sweden; Chile; Bolivia; Peru; South Africa; Tasmania; Australia; Acton, Canada.

In the United States in considerable quantities associated with allied sulphides of copper in the Butte, Montana, district. In smaller quantities at Bristol, Conn.; Chesterfield, Mass., etc.

An important ore of copper.

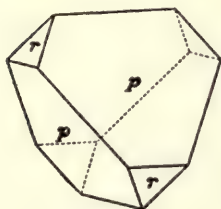


FIG. 28.

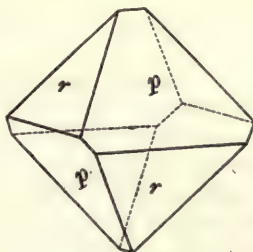


FIG. 29.

CHALCOPYRITE, Copper Pyrites, Yellow Copper Ore, CuFeS_2 .

Tetragonal, scalenohedral class. $a : c = 1 : 0.98525$. Crystals are often greatly distorted and, hence, difficult to interpret. Bisphenoidal and pyramidal habits are common, Figures 28 and 29. Faces of large crystals are often dull, striated, and furrowed. The positive unit bisphenoid faces

p are commonly dull while those of the negative form *r* are smooth and brilliant. Contact and penetration twins according to several laws. Repeated, supplementary, and cyclic twins. Most commonly found in compact masses.

Conchoidal to uneven fracture. Pyramidal cleavage is rarely observed. Hardness 3.5 to 4. Specific gravity 4.1 to 4.3. Brittle. Brass to gold yellow in color. Tarnishes to various blue, purple, and black tints. Iridescent. Greenish black streak.

CuFeS_2 , contains at times small but valuable amounts of gold and silver; also selenium, thallium, and arsenic. Fusible to a grayish black magnetic globule. Soluble in nitric acid with separation of sulphur.

Most common copper mineral. Usually found with pyrite, sphalerite, bornite, pyrrhotite, cobalt and nickel minerals, siderite, tetrahedrite, malachites, azurite, galena, cassiterite, and chalcocite.

Chalcopyrite is found extensively in gneiss at Falun, Sweden; Mansfield, Germany; Rio Tinto, Spain; Hartz Mountains; Freiberg district, Saxony; in tin ore deposits Cornwall, England; Bohemia; Tuscany; Chile; New South Wales; Japan; Sudbury district, Canada.

In the United States chalcopyrite occurs widespread. Especially so in Bingham, Utah; Bisbee, Arizona; Butte district, Montana; Ducktown, Tennessee; Colorado; Pennsylvania, etc.

An important ore of copper.

Linnaeite, Cobalt Pyrites, $(\text{Ni}, \text{Co})_3\text{S}_4$.

Cubic, hexoctahedral class. Well developed octahedral crystals, sometimes showing the cube in combination. Twins according to the Spinel law. Compact and disseminated; in granular aggregates.

Imperfect cubical cleavage. Uneven fracture. Brittle. Hardness 5.5. Specific gravity 4.8 to 5.8. Metallic luster. Reddish steel gray in color. Tarnishes copper red and yellow. Grayish black streak.

$(\text{Ni}, \text{Co})_3\text{S}_4$, often with iron and copper. The chemical composition varies considerably. Sometimes supposed to be $(\text{Co}, \text{Ni})_4\text{S}_5$ or Co_3S_4 . On charcoal yields fumes of sulphur dioxide and a magnetic globule. Soluble in nitric acid to a red solution with separation of sulphur.

Does not occur extensively. Is usually associated with chalcopyrite, pyrrhotite, hematite, bornite, and the cobalt and nickel minerals. Found at Bastnaes, Sweden; Müsen, Prussia; Mine La Motte, Missouri; Mineral Hill, Maryland; Lovelock's Station, Nevada; and elsewhere.

Used as a source of nickel and cobalt.

MIARGYRITE-ZINKENITE GROUPS

Here are placed metasulph-arsenites and antimonites, etc., of thallium, silver, copper, and lead. These minerals conform to the general formulae, $M'R'''S_2$ or $M'R'''S_4$.

Two series, depending upon crystallization, may be differentiated.

MIARGYRITE GROUP

(*Monoclinic Prismatic Class*)

	<i>a</i>	:	<i>b</i>	:	<i>c</i>	
LORANDITE, $TlAsS_2$.	0.6827	:	1	:	0.6650,	$\beta=90^\circ 17'$.
MIARGYRITE, $AgSbS_2$.	0.7479	:	1	:	0.6432,	$\beta=91^\circ 40'$.

ZINKENITE GROUP

(*Orthorhombic Bipyramidal Class*)

	<i>a</i>	:	<i>b</i>	:	<i>c</i>	
EMPLECTITE, $Cu_2Bi_2S_4$.	0.5430	:	1	:	0.6256	
SCLEROCLASE, $PbAs_2S_4$.	0.5389	:	1	:	0.6188	
ZINKENITE, $PbSb_2S_4$.	0.5575	:	1	:	0.6353	

None of the minerals of these groups are of economic importance.

LORANDITE, $TlAsS_2$. Occurs as tabular, monoclinic crystals. Usually small. Flexible. Good cleavage in three directions. Hardness 2 to 2.5. Specific gravity 5.53. Adamantine luster. Cochineal to carmine red in color. Dark cherry red streak. Found only on realgar at Allchar, Macedonia.

MIARGYRITE, $AgSbS_2$. Small, monoclinic crystals; acicular or tabular. Also compact and disseminated. Conchoidal fracture. Hardness 2 to 2.5. Specific gravity 5.18 to 5.3. Metallic luster. Steel or lead gray to black in color. Deep blood red in thin splinters. Streak cherry red. Found in silver ore deposits, Freiberg, Saxony; Příbram, and Felsöbánya, Bohemia; Hartz Mountains; Spain; Mexico.

EMPLECTITE, $Cu_2Bi_2S_4$. Orthorhombic. Long-needle-like crystals. Striated. Often poorly developed. Pinacoidal cleavage. Compact and disseminated. Uneven fracture. Hardness 2. Specific gravity 6.23 to 6.38. Tin white to steel gray in color. Tarnishes darker. Black streak. In quartz at Schwarzenberg, Saxony; Wittichen, Black Forest, Baden.

SCLEROCLASE, Sartorite, $PbAs_2S_4$. Small, thin, needle-like crystals belonging to the orthorhombic system. Often striated. Basal cleavage. Very brittle. Hardness 3. Specific gravity 5.4. Light lead gray with red brown streak. Occurs with dufrenoy-site in the dolomite of the Binnenthal, Switzerland.

ZINKENITE, Zinckenite, $PbSb_2S_4$. Orthorhombic, radial, acicular crystals, usually showing a combination of the unit prism and macrodome. Pseudo-hexagonal due to twinning. Fibrous, columnar, and massive. Easily broken. Hardness 3 to 3.5. Specific gravity 5.3 to 5.35. Dark to lead gray. Tarnishes. Black streak. With stibnite at Wolfsberg, Hartz Mountains; Hausach, Switzerland; Sevier Co., Arkansas; San Juan Co., Colorado; Eureka, Nevada.

PLAGIONITE, $\text{Pb}_5\text{Sb}_8\text{S}_{17}$. Monoclinic, prismatic class. $a : b : c = 1.1331 : 1 : 0.4228$, $\beta = 107^\circ 10'$. Small thick tabular crystals consisting of basal and orthopinacoids with several hemipyramids. Basal pinacoid is usually smooth, other faces striated. Hardness 2.5. Specific gravity 5.4 to 5.6. Dark lead gray to iron black. Black streak. Occurs at Wolfsberg, Hartz Mountains; Goldkronack, Bavaria.

JAMESONITE GROUP

The members of this group can be referred to the general formula $\text{M}''_2\text{R}'''\text{S}_5$. R''' may be arsenic, antimony, or bismuth.

DUFRENOYSITE, $\text{Pb}_2\text{As}_2\text{S}_5$.

Monoclinic System

JAMESONITE, $\text{Pb}_2\text{Sb}_2\text{S}_5$.

Orthorhombic System

COSALITE, $\text{Pb}_2\text{Bi}_2\text{S}_5$.

Orthorhombic System

The minerals of this group occur very sparingly.

DUFRENOYSITE, $\text{Pb}_2\text{As}_2\text{S}_5$. Monoclinic, prismatic class. $a : b : c = 0.6510 : 1 : 0.6126$, $\beta = 90^\circ 33\frac{1}{2}'$. Sometimes considered orthorhombic. Crystals usually large, thick tabular or columnar, highly modified, but rare. Striated. Compact, massive. Basal cleavage. Brittle. Hardness 3. Specific gravity 3.5 to 3.6. Dark lead gray color. Red brown streak. With scleroclase in the dolomite of the Binnenthal, Switzerland.

JAMESONITE, $\text{Pb}_2\text{Sb}_2\text{S}_5$. Orthorhombic, bipyramidal class. $a : b : c = 0.8195 : 1 : ?$ Long, acicular crystals. Usually without good terminations. Commonly in parallel or divergent crystal aggregates. Easily broken. Compact, massive. Basal cleavage. Hardness 2 to 2.5. Specific gravity 5.52 to 5.8. Steel gray to dark lead gray. Streak gray to black. $\text{Pb}_2\text{Sb}_2\text{S}_5$, with iron, silver, copper, or zinc. Occurs at Cornwall, England; Spain; Sevier Co., Arkansas.

COSALITE, $\text{Pb}_2\text{Bi}_2\text{S}_5$. Orthorhombic. Striated, prismatic crystals. Also massive, fibrous, or radiated. Lead to blue gray in color. Specific gravity 6.39 to 6.75. Usually contains silver. Cosala, Province Sinaloa, Mexico; Sweden; Mexico; Comstock mine, La Plata Co., and Alaska mine, Ouray Co., Colorado.

BOULANGERITE GROUP

The members of this group conform to the general formula $\text{M}''_5\text{R}'''_4\text{S}_{11}$.

BOULANGERITE, $\text{Pb}_5\text{Sb}_4\text{S}_{11}$.

Orthorhombic System

DIAPHORITE, $\left\{ \right.$

$(\text{Pb}, \text{Ag}_2)_5\text{Sb}_4\text{S}_{11}$. $\left\{ \right.$ Orthorhombic System

FREIESLEBENITE, $\left\{ \right.$

$\left\{ \right.$ Monoclinic System

The compound $(\text{Pb}, \text{Ag}_2)_5\text{Sb}_4\text{S}_{11}$ is dimorphous. Its monoclinic modification, freieslebenite, is the more important mineral.



BOULANGERITE, $\text{Pb}_6\text{Sb}_4\text{S}_{11}$. Orthorhombic, bipyramidal class. $a : b : c = 0.5527 : 1 : 0.7478$. Prismatic crystals. Very rare. In crystalline, granular masses. Hardness 2.5 to 3. Specific gravity 5.8 to 6.2. Dull metallic luster. Dark lead gray color. Satin-like shimmer. Black streak. Often with yellow spots of Sb_2O_3 . Occurs usually with stibnite. Not common. Wolfsberg, Hartz Mountains; Příbram, Bohemia; Tuscany; Tyrol; Sweden; Ural Mountains; Nevada.

FREIESLEBENITE, $(\text{Pb}, \text{Ag}_2)_8\text{Sb}_4\text{S}_{11}$. Monoclinic, prismatic class. $a : b : c = 0.5872 : 1 : 0.9278$, $\beta = 92^\circ 14'$. Prismatic crystals. Often striated. Twins. Compact and disseminated. Conchoidal fracture. Hardness 2 to 2.5. Specific gravity 6.2 to 6.4. Lead to light steel gray, tarnishes black. Gray streak. Found at Freiberg, Saxony; Hungary; Spain; Augusta Mountain, Gunnison Co., Colorado.

PYRARGYRITE GROUP

This group consists of the orthosulph-arsenite and antimonite of silver.

Hexagonal System $a : c$

Proustite, Ag_3AsS_3 . Ditrigonal Pyramidal Class $1 : 0.8038$

Pyrargyrite, Ag_3SbS_3 . Ditrigonal Pyramidal Class $1 : 0.7892$

Although these two minerals differ materially in color, it is not always easy to distinguish them. This can be done, however, by means of the streak, specific gravity, goniometric measurements, as also by the blowpipe.

Proustite, Light Ruby Silver Ore, Light Red Silver Ore, Ag_3AsS_3 .

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 0.8038$. Commonly prismatic, trigonal or ditrigonal pyramidal in habit. Hemimorphic development sometimes distinct. Crystals highly modified, distorted, and often difficult to interpret. Twins according to several laws. Massive, disseminated, as a coating or dendritic.

Imperfect pyramidal cleavage. Conchoidal fracture. Brittle. Hardness 2.5. Specific gravity 5.58 to 5.64. Brilliant adamantine luster. Translucent to transparent. Color and streak scarlet to vermilion.

Ag_3AsS_3 , at times contains some antimony. On charcoal yields fumes of As_2O_3 , garlic and sulphurous odors, and a globule of silver.

Occurs with pyrargyrite in veins with other silver minerals and galena. Calcite is commonly the gangue mineral. Occurs at Freiberg, Saxony; Joachimsthal, Bohemia; Chalanches, Dauphiné; Chañarcillo, Chile; Mexico; Spain; Peru; Cobalt district, Canada.

In the United States in the Ruby Silver district, Gunnison Co., also in San Miguel Co., Summit Co., and Ouray Co., Colorado; Comstock lode and Daney mine, Nevada; Poor Man's lode, Idaho; Arizona.

An important ore of silver.

Pyrargyrite, Dark Red Silver Ore, Dark Ruby Silver Ore, Ag_3SbS_3 .

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 0.7892$. Highly modified and complex crystals. Difficult to interpret, being often greatly distorted. Hemimorphic. Usually prismatic, trigonal and ditrigonal pyra-

midal in habit. Many forms have been observed. Twins according to several laws. Also compact, disseminated, as a coating and dendritic.

Imperfect pyramidal cleavage. Conchoidal to splintery fracture. Somewhat brittle. Hardness 2.5 to 3. Specific gravity 5.85, less if arsenic is present, 5.77 to 5.85. Metallic adamantine luster. In reflected light, dark red to lead gray in color; in transmitted light, deep red. Transparent only in thin splinters. Purple or cherry red streak.

Ag_3SbS_3 , usually with a little arsenic. Easily fusible; yields on charcoal a coating of Sb_2O_3 and a globule of silver. Occurs as a pseudomorph after argente.

Occurrence similar to that of proustite. Found in veins with other silver ores, calcite, galena, etc. Thus in the Freiberg district, Saxony; Gonderbach, Westphalia; Příbram, etc., Bohemia; Spain; Mexico; Chile; Colorado; Nevada; Arizona; Cobalt district, Canada, etc.

An important ore of silver.

BOURNONITE GROUP

This group embraces two minerals conforming to the general formula $\text{M}''_3\text{R}'''_2\text{S}_6$, in which R''' may be antimony or bismuth, and M'' lead or copper.

Bournonite, $\text{Pb}_2\text{Cu}_2\text{Sb}_2\text{S}_6$.

Orthorhombic System

AIKINITE, $\text{Pb}_2\text{Cu}_2\text{Bi}_2\text{S}_6$.

Orthorhombic System

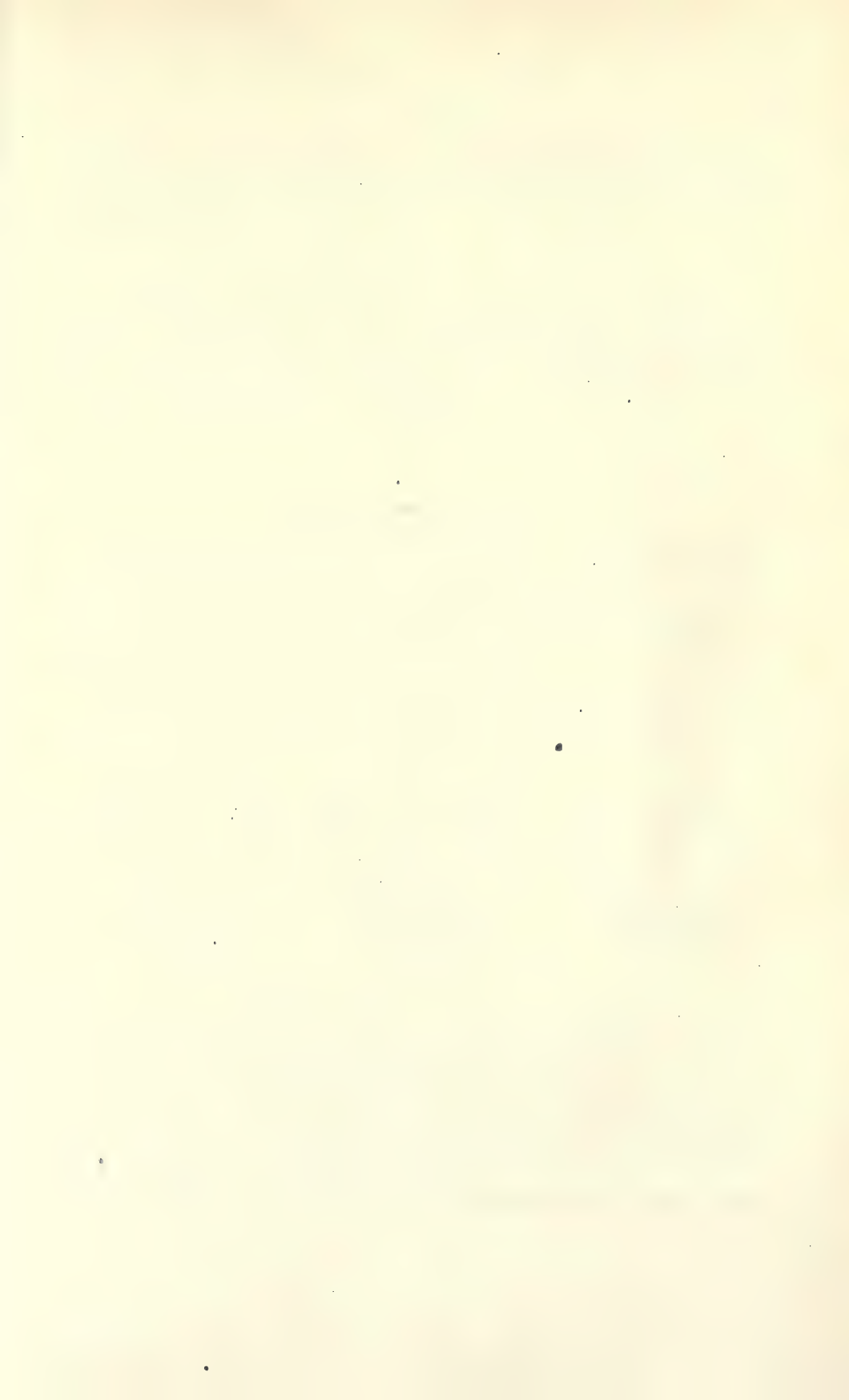
Seligmannite, the corresponding arsenic compound $\text{Pb}_2\text{Cu}_2\text{As}_2\text{S}_6$, is sometimes added to the above group. Its composition is, however, still in doubt. Seligmannite is a very rare mineral.

Bournonite, Wheel Ore, $\text{Pb}_2\text{Cu}_2\text{Sb}_2\text{S}_6$.

Orthorhombic, bipyramidal class. $a : b : c = 0.9379 : 1 : 0.8968$. Thick tabular crystals of a tetragonal habit; also prismatic. Vertical striations. Common forms are unit prism, basal, macro- and brachypinacoids, brachydomes, and various bipyramids. Basal pinacoid usually predominates. Twins common, twinning plane parallel to unit prism. Contact and interpenetration twins giving rise to *cross* and *cog-wheel* crystals. Also compact, granular, and disseminated masses.

Imperfect brachypinacoidal cleavage. Conchoidal fracture. Brittle. Hardness 2.5 to 3. Specific gravity 5.7 to 5.9. On fresh fracture surface greasy metallic luster. Crystals often dull. Steel to lead gray, also iron black in color. Gray to black streak.

$\text{Pb}_2\text{Cu}_2\text{Sb}_2\text{S}_6$, usually contains arsenic, but never silver. Easily fusible, yields metallic globule, also antimony and lead coatings. Globule colors flame green.



Occurs with galena, sphalerite, stibnite, tetrahedrite, chalcocite, etc., in the Hartz Mountains; Freiberg, Saxony; Příbram, Bohemia; Kapnik, Hungary; Mexico; Chile; Peru; Bolivia; Arizona; Arkansas; Colorado; Ontario; Siberia.

Important ore of lead and copper.

AIKINITE, Patrinite, $\text{Pb}_2\text{Cu}_2\text{Bi}_2\text{S}_6$.

Orthorhombic, bipyramidal class. $a : b : c = 0.9719 : 1 : ?$ Striated, acicular crystals. Oftentimes bent and twisted. No distinct terminations. Conchoidal fracture. Brittle. Hardness 2.5. Specific gravity 6.757. Metallic luster. Lead to steel gray; various tarnish colors, usually brown or black. Easily fusible. With gold in quartz veins at Beresowsk, Ural Mountains; also in Georgia.

Gold sometimes occurs as a pseudomorph after aikinite.

TETRAHEDRITE GROUP

The tetrahedrites possess the general formulae $\text{M}''_4\text{R}'''_2\text{S}_7$ or $\text{M}'_4\text{M}''_2\text{R}'''_2\text{S}_7$, in which M' indicates copper, mercury, or silver; M'' either iron or zinc, and R''' arsenic or antimony. Several varieties may be differentiated. All crystallize in the hextetrahedral class of the cubic system.

TETRAHEDRITE, Gray Copper Ore, $\text{M}''_4\text{R}'''_2\text{S}_7$ or $\text{M}'_4\text{M}''_2\text{R}'''_2\text{S}_7$.

Cubic, hextetrahedral class. Excellent crystals showing tetrahedral development. Often highly modified. Many forms have been observed. Fig-

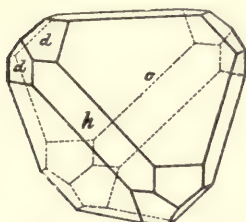


FIG. 30.

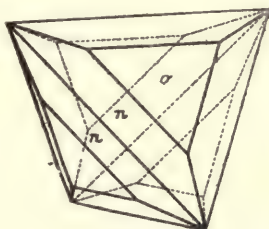


FIG. 31.

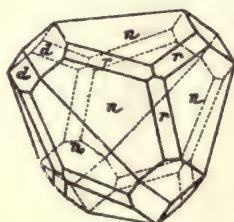


FIG. 32.

ures 30, 31, and 32 show some of the more common combinations; h =cube, o =positive tetrahedron, d =rhombic dodecahedron, n =trigonal tristetrahedron ($m=2$), and r =tetragonal tristetrahedron ($m=3/2$). The faces of the tetrahedron are often smooth and brilliant, but sometimes may show triangular striations. Penetration twins according to the Spinel law. Supplementary twins not very common, face of the cube acts as twinning plane. Massive, granular, disseminated, and compact.

No distinct cleavage. Conchoidal to uneven fracture. Brittle. Hard-

ness 3 to 4. Specific gravity 4.36 to 5.6. Metallic luster, sometimes rather dull. Opaque. Steel gray to iron black, often with brilliant tarnish colors. Sometimes covered with a fine crystalline coating of chalcopyrite or sphalerite. Streak black, also reddish brown.

According to the chemical composition many varieties may be differentiated. A few of the more important varieties are the following:

Cupriferous tetrahedrite. This variety contains, aside from copper, iron, zinc, and small amounts of silver, also antimony with a little arsenic. Specific gravity 4.5 to 5. Hardness 3 to 4. A common variety.

Argentiferous tetrahedrite, (*Freibergite*). Contains as high as 31% of silver. Usually free from arsenic. Specific gravity 4.83 to 5.

Mercurial tetrahedrite, (*Schwartzite*). Contains as much as 18% of mercury; also antimony and arsenic. Specific gravity 5 to 5.6.

Arsenical tetrahedrite, (*Tennantite*). Contains no silver or mercury and very little antimony. Its composition may in general be expressed by the formula $(\text{Cu}_2, \text{Fe}, \text{Zn})_4\text{As}_2\text{S}_7$. Specific gravity 4.4 to 4.9.

The different varieties fuse easily to a gray globule and are soluble in aqua regia. Tetrahedrites on decomposing form malachite, azurite, bournonite, cinnabar, chalcopyrite, and so forth.

Tetrahedrite occurs associated with the various sulphide minerals of copper, silver, lead, and so forth; especially, chalcopyrite, sphalerite, galena, bournonite, and pyrite. Also quartz, siderite, and barite are common associates. Found at Freiberg, Saxony; Clausthal, Hartz Mountains; Black Forest, Baden; Příbram, Bohemia; Kapnik, Hungary; Mexico; Bolivia; Chile, and Tuscany.

In the United States at Butte, Montana; in many places in Colorado; Nevada; and Arizona.

An important copper and silver ore.

JORDANITE GROUP

This group contains two minerals which possess the general composition $\text{Pb}_4\text{R}'''_2\text{S}_7$ where R''' indicates arsenic or antimony.

JORDANITE, $\text{Pb}_4\text{As}_2\text{S}_7$.

Monoclinic Prismatic Class

MENEGHINITE, $\text{Pb}_4\text{Sb}_2\text{S}_7$.

Orthorhombic Bipyramidal Class

JORDANITE, $\text{Pb}_4\text{As}_2\text{S}_7$. Monoclinic, prismatic class. $a : b : c = 0.4945 : 1 : 0.2655$, $\beta = 90^\circ 33\frac{1}{2}'$. Pseudohexagonal due to twinning parallel to the unit prism. Crystals highly modified. Perfect clinopinacoidal cleavage. Dark lead gray in color, often tarnished. Hardness 3. Specific gravity 6.4. Streak black. Rare mineral. Found with dufrenoyite in the dolomite of the Binnenthal; Nagyág, Transylvania.

MENECHINITE, $\text{Pb}_4\text{Sb}_2\text{S}_7$. Orthorhombic, bi pyramidal class. $a : b : c = 0.4747 : 1 : 0.3428$. Although orthorhombic it is considered isomorphous with jordanite. Slender prismatic crystals. Usually striated. Fibrous and compact masses. Is similar to stibnite in appearance. Metallic luster. Hardness 2.5. Specific gravity 6.34 to 6.43. Brittle. Blackish lead gray color. With emery at Schwarzenberg, Saxony; Tuscany; Marble Lake, Ontario.

STEPHANITE GROUP

Here are placed the sulphantimonates of silver and lead which possess the general formula $\text{M}''_5\text{Sb}_2\text{S}_8$.

Stephanite, $\text{Ag}_{10}\text{Sb}_2\text{S}_8$.

Orthorhombic System

GEOCRONITE, $\text{Pb}_5\text{Sb}_2\text{S}_8$.

Orthorhombic System

Stephanite, Brittle Silver Ore, $\text{Ag}_{10}\text{Sb}_2\text{S}_8$.

Orthorhombic, bi pyramidal class. $a : b : c = 0.6291 : 1 : 0.6851$. Thick tabular or prismatic crystals. Rosette and step-like groups. Highly modified. Pseudohexagonal in simple as well as twinned crystals. Twinning plane parallel to unit prism. Repeated twins, also trillings. Compact, disseminated, and as a coating.

Brachypinacoidal cleavage. Conchoidal to uneven fracture. Soft but brittle. Hardness 2 to 2.5. Specific gravity 6.2 to 6.3. Metallic luster. Lead gray to iron black. Black streak.

$\text{Ag}_{10}\text{Sb}_2\text{S}_8$, contains arsenic, iron, and copper. Fuses easily and yields on charcoal a white coating and dark gray globule of silver.

Occurs with other silver ores at Joachimsthal, Bohemia; Freiberg, Saxony; Andreasberg, Hartz Mountains; Sardinia; Peru; Comstock lode, and elsewhere, Nevada; various places in Idaho.

An important ore of silver.

GEOCRONITE, $\text{Pb}_5\text{Sb}_2\text{S}_8$. Crystals are very rare. Supposed to be orthorhombic and isomorphous with stephanite. Usually compact. Conchoidal fracture. Hardness 2 to 3. Specific gravity 6.4 to 6.54. Light lead gray color, tarnishes black. Occurs in Sweden, Spain, and Tuscany.

POLYBASITE GROUP

The members of this group have the general formula $\text{M}'_9\text{R}'''\text{S}_6$, where M indicates silver or copper, and R either arsenic or antimony.

PEARCEITE, $(\text{Ag,Cu})_9\text{AsS}_6$.

Monoclinic System

Polybasite, $(\text{Ag,Cu})_9\text{SbS}_6$.

Monoclinic System

PEARCEITE, $(\text{Ag,Cu})_9\text{AsS}_6$. Monoclinic, prismatic class. $a : b : c = 1.7309 : 1 : 1.6199$, $\beta = 90^\circ 9'$. Crystals are rhombohedral in development. Brittle. Hardness 3.

Specific gravity 6.13 to 6.17. Black in color and streak. Found at Aspen, Colorado; Marysville, Montana; Chile.

Polybasite, $(\text{Ag,Cu})_9\text{SbS}_6$.

Monoclinic, prismatic class. $a : b : c = 1.7309 : 1 : 1.5796$, $\beta = 90^\circ$. Pseudo-hexagonal. Prism angle $119^\circ 58'$. Six-sided thick tabular crystals consisting of a combination of the basal pinacoid with pyramids. Compact and disseminated. Triangular striations on basal pinacoid.

Perfect basal cleavage. Uneven fracture. Hardness 2 to 2.5. Specific gravity 6 to 6.25. Metallic luster. Iron black. Thin splinters in transmitted light are cherry red. Black streak.

$(\text{Ag,Cu})_9\text{SbS}_6$, may contain arsenic, iron, and zinc. Easily fusible. Yields on charcoal white fumes of antimony trioxide and odor of sulphur dioxide. The residue reacts for copper and silver.

Occurs with other silver minerals at Freiberg, Saxony; Andreasberg, Hartz Mountains; Příbram, Bohemia; Hungary; Comstock lode and elsewhere, Nevada; Colorado; Arizona; Cobalt district, Ontario.

An ore of silver.

POLYARGYRITE, $\text{Ag}_{21}\text{Sb}_2\text{S}_{15}$. Cubic, hexoctahedral class. Very small, distorted crystals. Octahedron, cube, and rhombic dodecahedron are usually in combination. Cubical cleavage. Hardness 2.5. Specific gravity 6.974. Malleable. Dark lead gray to iron black in color. Occurs at Wolfach in the Black Forest, Baden.

ENARGITE GROUP

The members of this group are orthosulpho-salts of copper and conform to the general formula Cu_3RS_4 , where R is pentavalent arsenic or antimony.

Enargite, Cu_3AsS_4 .

(Luzonite)

Orthorhombic System

FAMATINITE, Cu_3SbS_4 .

?

Until recently Cu_3AsS_4 was supposed to be dimorphous. Moses has, however, shown that the luzonite, which was formerly considered as the second modification, conforms in every respect, crystallographically, to enargite. Luzonite is, hence, only a variety of enargite.

Enargite, Cu_3AsS_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.8694 : 1 : 0.8308$. Small prismatic crystals with vertical striations. The usual combination consists of the unit prism, the three pinacoids, and unit brachydome. Penetration

twins and star-shaped trillings; twinning plane parallel to the marcoprism ($n=3/2$). Usually found in compact, fine or coarse grained masses.

Perfect prismatic cleavages; distinct cleavages parallel to the three pinacoids also to be observed. Uneven fracture. Hardness 3. Specific gravity 4.33 to 4.47. Brittle. Submetallic luster. Steel gray to iron black. In artificial light resembles sphalerite. Streak black. Opaque.

Cu_3AsS_4 , may contain small amounts of iron and zinc replacing the copper, and some antimony in place of arsenic. Fuses on charcoal and yields garlic odor of arsenic. With soda gives a copper globule. Soluble in nitric acid with separation of sulphur.

In veins with other copper minerals. Not very common in Europe. Found at Pardid, Hungary, and Brixlegg, Tyrol. More extensive in Peru, Chile, Argentine Republic, Bolivia, Mexico, and the Island of Luzon in the Philippines.

In remarkably large deposits in the copper mines of the Butte district, Montana; also in Colorado; Tintic district, Utah, etc.

A very important ore of copper.

FAMATINITE, Cu_3SbS_4 . Practically nothing is known of the crystallography of this mineral but on account of its chemical composition it is considered isomorphous with enargite. May contain as high as 9% of arsenic. Massive. Fracture uneven. Brittle. Hardness 3.5. Specific gravity 4.57. No cleavage. Reddish steel gray in color.

A rare mineral. Found with other copper minerals and pyrite in Serra de Famatina, Argentine Republic; also in Cerro de Pasca, Peru.

Stannite, Tin Pyrites, Bell-Metal Ore, $\text{Cu}_2\text{FeSnS}_4$.

Tetragonal, scalenohedral class. $a : c = 1 : 0.986$. Exceedingly small bisphenoidal crystals. Very rare. Usually compact, granular, or disseminated masses. Uneven fracture. Brittle. Hardness 4. Specific gravity 4.3 to 4.52. Metallic luster. Steel gray to iron black in color. Tarnishes blue. Streak black.

$\text{Cu}_2\text{FeSnS}_4$, often contains admixture of finely divided chalcopyrite. Fuses with difficulty; yields a white coating on charcoal, also metallic globule. Soluble in nitric acid, yielding a green solution with the separation of tin dioxide and sulphur.

Rare mineral. Usually found with cassiterite, and so forth, in tin ore deposits. Thus at Cornwall, England; Guanuni and Potosi, Bolivia; Black Hills, South Dakota.

ARGYRODITE GROUP

This group includes but two members, sulpho-germanates of silver, which conform to the general formula Ag_8GeS_6 . Germanium may be partially replaced by tin.

CANFIELDITE, $\text{Ag}_8(\text{Sn,Ge})\text{S}_6$.

Hexoctahedral Class

ARGYRODITE, Ag_8GeS_6 .

Hexoctahedral Class

CANFIELDITE, $\text{Ag}_8(\text{Sn,Ge})\text{S}_6$. Cubic, hexoctahedral class. Crystals indistinct. Compact and massive. Specific gravity 6.28. Black in color. Very much like argyrodite. Found at La Paz, Bolivia.

ARGYRODITE, Ag_8GeS_6 . Cubic, hexoctahedral class. Crystals are exceedingly small. Octahedrons alone or in combination with the rhombic dodecahedron. Compact and massive. No cleavage. Hardness 2.5. Specific gravity 6.26. Metallic luster. On fresh fracture reddish steel gray, elsewhere steel gray. Yields black sublimate in closed tube. Fuses on charcoal and yields a white sublimate which later turns yellow.

Rare. Occurs with marcasite in the Himmelsfürst mine, Freiberg, Saxony; also in Guanuni and Potosi, Bolivia.

The element germanium was discovered in argyrodite in 1886 by the late Professor Clements Winkler of the Freiberg School of Mines, Saxony.

FRANCKEITE, $\text{Pb}_8\text{Sn}_2\text{Sb}_2\text{S}_{12}$. Crystal form unknown. Occurs in small tabular or radial fibrous masses of a blackish lead gray color. Rare. Specific gravity 5.55. Occurs at Chocaya and Aullagas, Bolivia.

CYLINDRITE, $\text{Pb}_8\text{Sn}_6\text{Sb}_2\text{S}_{21}$. Crystal form unknown. Occurs in cylindrical aggregates with a dark lead gray color and metallic luster in the Province of Poopa, Bolivia. Hardness 2.5 to 3. Specific gravity 5.42. Very rare.

III. OXIDES, HYDROXIDES, ETC.

1. OXIDES

WATER, H_2O .

Above 0°C . water is a liquid, hence, amorphous. Almost colorless. In large quantities and when pure, it has a bluish tinge. Specific gravity, when pure, at 4°C . and 760 mm. barometric pressure is 1. That of ocean water may be as high as 1.028. Transparent and singly refractive, $n_{\text{Na}} = 1.3336$. When pure it is without odor or taste.

Water occurs very widely distributed in nature and is an important agency in the disintegration, decomposition, transportation, and formation of minerals. Nearly all minerals are more or less soluble in water, especially if it contain such substances as carbon dioxide, humus acid, hydrochloric acid, oxygen, etc., in solution. The ocean water contains about 3.44% of solid mineral matter in solution. The following 31 elements are found in solution in the ocean, some to be sure only in very small amounts: Iodine, fluorine, phosphorous, silicon, boron, bromine, silver, lead, copper, zinc, cobalt, arsenic, nickel, iron, manganese, aluminium, barium, strontium, lithium, caesium, rubidium, gold, sulphur, nitrogen, carbon, oxygen, calcium, magnesium, potassium, sodium, and chlorine. Hence, water is often called the universal solvent. When water freezes it expands. This increase in volume is estimated at 9 to 10% and the pressure exerted at 138 tons per square foot. Due to this enormous pressure, freezing water is an important geological agency, causing the widening of cracks and crevices thereby extending the zone of activity of water and oxygen and hastening weathering and decomposition.

ICE, Snow, H_2O .

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 1.617$. Water on freezing crystallizes, forming snow or ice. Snow crystals are often very beautiful. They are tabular, and hexagonal in outline, and show a great

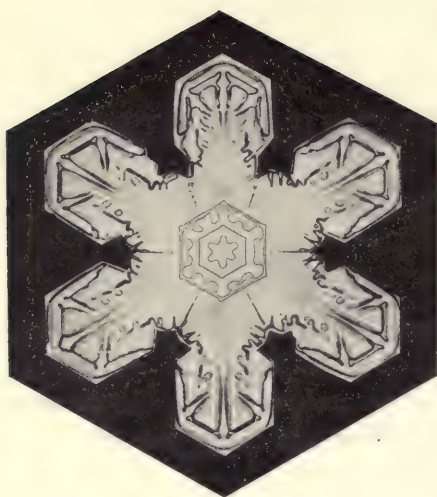


FIG. 33.

(Photograph by W. A. Bentley.)

diversity in development. Figure 33 represents a magnified snow crystal. Measurements of ice or snow crystals are obviously not very accurate. Lake or stream ice consists of crystals arranged in a definite manner. The c axes of the various crystal particles are all perpendicular to the extent of the sheet of ice, that is, they are vertical. This uniform crystallographic arrangement allows such ice to be easily split along definite planes. The definite orientation is shown by the columnar or prismatic structure, easily observed when lake or stream ice is subjected to partial

melting. Glacier ice differs from lake or stream ice in that the crystal particles do not possess a definite orientation. Ice also occurs stalactitic, as icicles.

Ice is usually colorless, in large masses greenish or bluish. Transparent. Weak double refraction, $n_{Na} = 1.309$, $n_{Na} = 1.333$ at -8°C .

Generally quite pure, but may contain impurities, principally as inclusions. This is especially the case of ice formed in disturbed water or near the shore.

TELLURITE, TeO_2 . Orthorhombic, $a : b : c = 0.4596 : 1 : 0.4650$. Thin tabular crystals. Striated. Often arranged in hemispherical masses. Adamantine luster. Transparent to translucent. White to honey yellow in color. Hardness 2. Specific gravity 5.9. Basal cleavage. Rare. With native tellurium at Zalathna, Transylvania; Boulder Co., Colorado; also South Dakota.

TUNGSTITE, $\text{WO}_3 \cdot \text{H}_2\text{O}$. Orthorhombic, $a : b : c = 0.6966 : 1 : 0.4026$ (artificial crystals). Occurs in nature only as powdery and earthy masses. Artificial crystals are transparent. Powdery masses are dull with yellow or greenish yellow color. Soft. Specific gravity 6.5 to 7.2. Rare. With wolframite and other tungsten minerals at Cornwall, England; Monroe, Conn.; Cabarrus Co., N. C.; with hübnerite at Osceola, Nevada.

SENARMONTITE GROUP

Here are placed the oxides of arsenic, antimony, and bismuth which possess the general formula M'''_2O_3 . One compound, Sb_2O_3 , is dimorphous.

CUBIC SERIES

ARSENOLITE, As_2O_3 .

Hexoctahedral Class

Senarmontite, Sb_2O_3 .

Hexoctahedral Class

ORTHORHOMBIC SERIES

VALENTINITE, Sb_2O_3 .

Bipyramidal Class

 $a : b : c$

0.3914 : 1 : 0.3367

BISMITE, Bi_2O_3 .

Bipyramidal Class

0.8166 : 1 : 1.0649

The axial ratio given for bismite is for artificial crystals, natural crystals not being known. The isomorphism between valentinite and bismite is by no means fully established.

ARSENOLITE, Arsenite, As_2O_3 .

Cubic, hexoctahedral class. Artificial crystals are octahedral. In nature only as white or colorless crusts or coatings on arsenic minerals.

Conchoidal fracture. Octahedral cleavage. Hardness 1.5. Specific gravity 3.7. Dull to silky luster. Streak white. Astringent taste. Translucent. Yields on charcoal coating and odor of arsenic. Soluble in hydrochloric acid, also in hot water.

Arsenolite is a decomposition product of minerals containing arsenic. Occurs in small quantities at Andreasberg, Hartz Mountains; Joachimsthal, Bohemia; Kapnik, Hungary; Cornwall, England; Chile; Peru; California; Nevada.

Senarmontite, Sb_2O_3 .

Cubic, hexoctahedral class. Octahedral crystals. Also granular and compact masses. Octahedral cleavage. Conchoidal to uneven fracture. Hardness 2 to 2.5. Specific gravity 5.22 to 5.3. Greasy luster. Colorless, white and gray. Transparent to translucent. Sublimes. Soluble in hydrochloric acid.

Occurs with the decomposition products of minerals containing antimony. Found at Constantine, Algeria; Pernek, Hungary; Burke Co., N. C.; South Ham, Quebec; Sardinia.

VALENTINITE, Sb_2O_3 .

Orthorhombic, bipyramidal class. $a : b : c = 0.3914 : 1 : 0.3367$. Prismatic crystals, sometimes highly modified. Often in radiating groups. Also compact, columnar, fibrous, and granular aggregates. Perfect brachypinacoidal cleavage. Hardness 2.5. Specific gravity 5.6 to 5.8. Adamantine luster. White, gray to pale red. Translucent. Melts easily and sublimes. Soluble in hydrochloric acid.

A decomposition product of antimony minerals, especially stibnite. Valentinite is more abundant than senarmontite. Occurs at Wolfsberg, Hartz Mountains; Příbram, Bohemia; Constantine, Algeria; Sardinia; Burke Co., N. C.; and South Ham, Quebec.

BISMITE, Bismuth Ocher, Bi_2O_3 .

Orthorhombic, $a : b : c = 0.8166 : 1 : 1.0649$ (artificial crystals). In nature only as compact, disseminated, and earthy masses. Adamantine to dull luster. Translucent to opaque. Green and straw yellow, also grayish white in color. Soft. Specific gravity 4.36 (the artificial compound is much heavier, 8.07 to 8.86). Rare. Occurs at Schneeberg, Saxony; Joachimsthal, Bohemia; Hungary; Pala, California; Utah; Gaston Co., N. C.

QUARTZ GROUP

This is a very important group. It contains those minerals which possess the general formula MO_2 , where M is tetravalent and may be silicon, titanium, or zirconium. Depending upon the crystallization, four series may be differentiated.

HEXAGONAL SERIES

		$a : c$
QUARTZ, SiO_2.	Trigonal Trapezohedral Class	1 : 1.0999

ORTHORHOMBIC SERIES

		$a : b : c$
TRIDYMIT, SiO_2.	Bipyramidal Class	0.5774 : 1 : 0.9544
Brookite, TiO_2.	Bipyramidal Class	0.5941 : 1 : 1.1222

TETRAGONAL SERIES

		$a : c$
Anatase, TiO_2.	Ditetragonal Bipyramidal Class	1 : 1.7844
CRISTOBALITE, SiO_2.	?	?

MONOCLINIC SERIES

		$a : b : c$
BADDELEYITE, ZrO_2.	Prismatic Class	0.9768 : 1 : 1.0475, $\beta = 98^\circ 40'$

From the foregoing classification it is seen that SiO_2 and TiO_2 , including rutile page 77, are trimorphous. Quartz is by far the most important mineral of this group.

QUARTZ, Chalcedony, Agate, Jasper, etc. SiO_2 .

Hexagonal, trigonal trapezohedral class. $a : c = 1 : 1.0999$. Crystals are very common. Usually prismatic in habit, more rarely pyramidal. Often apparently holohedral, Figure 34. Over 140 forms have been observed of which the following are the most common: Prism of the first order a ;

positive and negative unit rhombohedrons r and z , respectively; the positive modified rhombohedrons where m equals 3 or 4; negative modified rhombohedron with $m=7$; the unit (s) and modified ($m=2$) trigonal bipyramids of the second order; and the three trigonal trapezohedrons where n equals $6/5$, $5/4$, $4/3$, and m is 6, 5, or 4, respectively. The most common of the three trigonal trapezohedrons is x with the coefficients n and m equal-

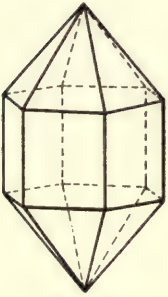


FIG. 34.

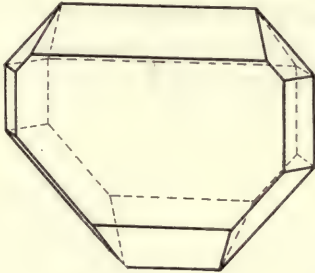


FIG. 35.

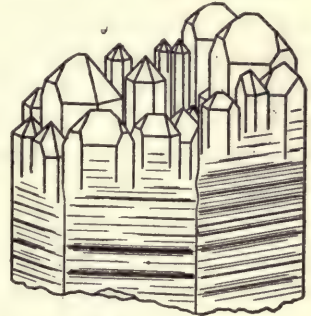


FIG. 36.

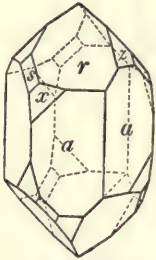


FIG. 37.

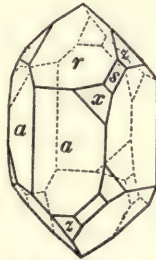


FIG. 38.

ing $6/5$ and 6. Figures 34, 35, 37 and 38 show some of the more common combinations. The basal pinacoid is very rarely observed. Crystals are often arranged in parallel groups, as shown in Figure 36 (after Tschermak); sometimes also grouped radially. It is not always possible to distinguish between the positive and negative unit rhombohedrons r and z . The prism faces are often striated horizontally. This is of use in the proper orientation of distorted crystals, which are rather common, Figure 35. Crystals are sometimes bent or twisted.

The presence of a trigonal trapezohedron, for example x in Figures 37 and 38, allows such crystals to be designated as *right-* or *left-handed* crystals. On *left-handed* crystals a face of the trigonal trapezohedron (x) lies in the upper left hand corner of the prism face a , Figure 37. In the case of *right-handed* crystals it is in the upper right hand corner, Figure 38.

Twins are very common. In many cases it is difficult to positively recognize the twinning. This can, however, be done by means of the optical or pyro-electric properties, as also by the etch-figures. Four of the more important twinning laws may be referred to. (1) *Common* or *Dauphiné law*, sometimes also called the *Swiss law*. Here two right- or left-handed crystals so interpenetrate that the positive rhombohedron of the one individual coincides with the negative of the other. This interpenetration causes a face of the trigonal trapezohedrons to appear, in the case of two right-handed crystals, in the upper right hand corner of each one of the prism faces (a). When two left-handed crystals interpenetrate the trigonal trapezohedron face (x) is to be observed in the upper left hand corner, Figure 39. This can be explained by the rotation of either one of the indi-

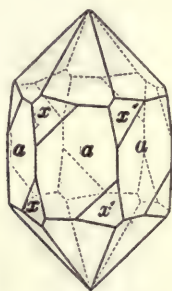


FIG. 39.

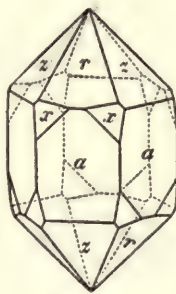


FIG. 40.

viduals through 180° about the c axis. Such twinned crystals are not symmetrical to a twinning plane but rather to a twinning axis, which in this case is the crystallographic c axis. (2) *Brazilian law*. A right- and a left-hand crystal of the same sign interpenetrate so that the twinned crystal is symmetrical to a plane parallel to a face of the prism of the second order, Figure 40. Such twins are in reality supplementary twins for they possess the symmetry of the ditrigonal scalenohedral class. This law is often observed on amethyst crystals from Brazil, hence, the name, *Brazilian law*. (3) *Prism of the first order* acts as the twinning plane. Here, right- and left-hand crystals interpenetrate. The twinned crystal is symmetrical, not only to the prism of the first order, but also to the basal pinacoid. (4) *Japan law*. These are contact twins with a face of the unit trigonal bipyramid acting as the twinning plane. The principal axes of the two individuals intersect at an angle of $84^\circ 35'$. Excellent crystals showing this law are found in Japan.

Quartz crystals often contain inclusions which may be liquids, gases, or solids. Rutile, chlorite, hematite, organic matter, asbestos, epidote, and

hornblende are among the solids found as inclusions in quartz. Carbon dioxide, either liquid or gaseous, is also noted as an inclusion. Sometimes scales of mica or hematite are distributed in a regular manner, so that such crystals may be separated into layers. Such crystals are called *cap quartz*.

Rhombohedral cleavages, generally indistinct and not commonly observed. These cleavages are made more pronounced by heating and rapid cooling. Conchoidal fracture is highly characteristic. Brittle. Hardness 7. Specific gravity ranges from 2.5 to 2.8; pure quartz 2.653 to 2.66. Vitreous luster, sometimes slightly 'greasy' on fracture surfaces. Transparent to opaque. When pure, quartz is colorless. Various shades of gray, yellow, red, blue, green, brown, and black are commonly noted. Many colors disappear when heated, thus, the violet color of the amethyst changes first to a yellow, then to a greenish tint, and when a temperature of 250°C. is reached, the crystal is colorless. Brown and smoky crystals usually become colorless when heated to 200°C. It is thought that the various colors may be due to the presence of organic matter or to small amounts of the oxides of some of the rarer elements. Streak white. Positive double refraction, $n_{Na} = 1.5442$, $n_{Na} = 1.5533$. Circular polarization. Often shows natural etch figures. Pyro-electric. Phosphoresces when rubbed.

SiO₂. May contain hematite, rutile, hornblende, chlorite, organic matter, and clay as impurities. Not attacked by the common acids. Easily acted upon by hydrofluoric acid; only slightly by potassium hydroxide. Infusible before the blowpipe. Common as a pseudomorph after many minerals, viz: Calcite, fluorite, siderite, etc.; also after wood, *silicified wood*. Only one mineral occurs as a pseudomorph after quartz, namely, talc.

The different varieties of quartz may be divided into three large groups, as follows: (a) *Phanerocrystalline*, (b) *Cryptocrystalline*, and (c) *Clastic* varieties.

(a) **Phanerocrystalline varieties** are vitreous, either crystallized or crystalline, and but slightly acted upon by potassium hydroxide. They include the following:

(1) **ROCK CRYSTAL**. This is ordinary crystallized quartz. Generally colorless.

(2) **AMETHYST**. This variety is purple to violet in color. Color may be due to manganese. Becomes colorless when heated, see above. Generally in crystals.

(3) **ROSE QUARTZ**. Usually massive. Pink to rose-red in color, becoming paler on exposure.

(4). **SMOKY QUARTZ**. Smoky yellow to dark brown or black. Often termed *cairngorm stone*. When black it is called *morion*. Becomes colorless when heated, see above.

(5) **MILKY QUARTZ.** Milk-white in color. Translucent or nearly opaque. Sometimes with a greasy luster.

(6) **YELLOW QUARTZ.** Light yellow in color. Often called *false topaz* or *citrine*. Citrine is sometimes produced by heating amethyst, see page 73.

(7) **AVENTURINE.** Quartz containing scales of mica, hematite, or goethite.

(8) **FERRUGINOUS QUARTZ.** Is colored brown or red, due to the presence of either limonite or hematite.

(9) **CHLORITIC QUARTZ.** Usually green. Contains chlorite as an inclusion.

(10) **RUTILATED QUARTZ.** Usually the rock crystal variety containing fine needles of rutile.

(11) **TIGER'S EYE.** Pseudomorph after crocidolite. Chatoyant luster.

(12) **CAT'S EYE.** Opalescent, due to inclusions of parallel fibers of asbestos. Grayish brown or green in color.

(b) **Cryptocrystalline varieties** are compact and homogeneous. Under the microscope they show a crystalline structure. More readily acted upon by potassium hydroxide than the crystalline varieties.

(1) **CHALCEDONY.** A transparent to translucent variety having a waxy luster. May be stalactitic, botryoidal, concretionary, and often lines cavities. Is white, grayish, pale to dark brown, blue, or black.

(2) **CARNELIAN OR SARD.** A red variety of chalcedony. Sometimes deep clear red, pale red, brownish red, or brown in color.

(3) **CHRYSOPRASE.** Apple green chalcedony.

(4) **PRASE.** Dull leek-green. Translucent.

(5) **PLASMA.** Bright to leek-green, sometimes emerald green.

(6) **HELIOTROPE OR BLOODSTONE.** Bright or dark green chalcedony with small spots of red jasper, irregularly distributed. The red spots resemble drops of blood.

(7) **AGATE.** This is chalcedony made up of strata or bands indicating various stages of deposition. The layers may be differently colored or clouded. This gives rise to several varieties of agate, namely, *banded*, *moss*, *clouded*, or *fortification agates*. In agates the banding is usually in parallel, but more or less wavy or irregular lines. Agates may be white, pale and dark brown, bluish, etc.

(8) **ONYX AND SARDONYX.** These are agates with the banding in parallel straight lines, corresponding to layers in even planes. In *onyx* the colors are generally white and black. In *sardonyx* red layers (carnelian) are also present.

(9) **JASPER.** Opaque, red, yellow, dark green, and grayish blue varie-

ties. When the colors are in broad bands or stripes, it is called *riband* or *striped jasper*.

(10) **FLINT**. Gray, smoky, brown, or brownish black, nodular variety, closely related to chalcedony. Usually found in chalk beds and limestones. Translucent. Possesses an excellent conchoidal fracture. Generally covered with a white coating.

(11) **HORNSTONE**. Is more brittle than flint. Has a splintery fracture.

(12) **CHERT**. A more or less general term applied to hornstone, impure flints or jaspers.

(13) **BASANITE**. A velvet-black variety used for the streaking of alloys of precious metals. Also called *touchstone* or *Lydian stone*.

(c) **Clastic varieties** of quartz include many of the silicious fragmental rocks. In some cases the individual particles are no longer distinct.

(1) **SAND**. In general, loose, unconsolidated grains or fragments of quartz.

(2) **SANDSTONE**. Consolidated sand. The cementing material may be silica, iron oxide, calcium carbonate, etc.

(3) **ITACOLUMITE**. A flexible sandstone. Contains some mica.

(4) **QUARTZITE OR GRANULAR QUARTZ**. Metamorphosed sandstone. The quartz particles are usually not recognizable by the naked eye.

Quartz is, next to water, the most common of all minerals. It is a very important rock-forming mineral, being a primary constituent of many igneous and sedimentary rocks. It may be formed from fusion, solution, or by sublimation. Quartz occurs in rocks of all ages and in many ore deposits. It is also found abundantly as sand and gravel.

Rock crystal, amethyst, smoky quartz, cat's eye, tiger's eye, rose quartz, chalcedony, agate, and jasper are used in jewelry and for ornamental purposes; agate and chalcedony for mortars and pestles; rock crystal for dishes, vases, optical instruments, and spectacles; sand for mortar and plaster, glass, and sandpaper; sandstone for building and paving purposes, and grindstones; and ground or crushed quartz and flint in wood fillers, pottery, scouring and polishing soaps, and as an abrasive.

TRIDYMITE, SiO_2 .

Occurs in two modifications. One is hexagonal, $a : c = 1 : 1.629$, and is formed at high temperatures. Below 130°C . tridymite is orthorhombic, $a : b : c = 0.5774 : 1 : 0.9544$. These crystals are generally trillings with an hexagonal development. Crystals are usually small and thin tabular. Cyclic twins according to several laws are quite common. Crystals are sometimes arranged in spherical or fan-shaped groups.

Basal parting. Hardness 6.5 to 7. Specific gravity 2.28 to 2.34 (quartz 2.65). Vitreous luster. White, colorless, yellow, or brown. Transparent to translucent.

SiO_2 , usually quite pure. Infusible before the blowpipe. Soluble in a hot, con-

centrated solution of sodium carbonate. Yields a skeleton of silica in salt of phosphorous bead.

First found in the trachyte of Mt. San Cristobal, near Pachuca, Mexico. Occurs also in other acid igneous rocks, such as andesite, liparite, etc.; occasionally in basalt. Found in the trachyte of Siebengebirge, near Bonn, Germany; Transylvania; Italy; France; Mt. Rainier, Washington; Yellowstone Park, etc. Not a common mineral

Brookite, TiO_2 .

Orthorhombic, bipyramidal class. $a : b : c = 0.5941 : 1 : 1.1222$. Usually as pyramidal or prismatic crystals. Figure 41 shows a crystal of the pyramidal habit, which consists of a combination of the unit prism (p) and the brachy bipyramid (e). The prismatic type is rarer. It is sometimes termed *arkansite*. Many forms have been observed on brookite.

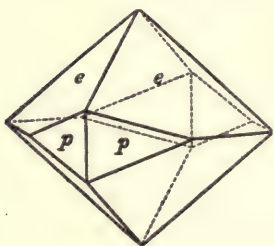


FIG. 41.

Indistinct brachypinacoidal cleavage. Brittle. Hardness 5.5 to 6. Specific gravity 3.8 to 4.1. On heating the specific gravity increases to that of rutile, page 78. Metallic-adamantine luster. Translucent to opaque. Red brown, reddish black, or iron black (*arkansite*) in color. Yellow white to brown streak.

TiO_2 , may contain ferric oxide. Reactions same as for rutile, page 78. Alters by paramorphism to rutile.

Occurs in various crystalline schists and silicate rocks, also in gold placers. Found at Tremaddoc, Wales; St. Gotthard, Switzerland; Miask, Ural Mountains; Magnet Cove, Arkansas, (*arkansite*); in the placers of North Carolina, etc.

CRISTOBALITE, SiO_2 .

Tetragonal. Octahedral crystals with skeletal development. Spinel-like twins. At and above 175°C . cristobalite is cubic. White in color. Translucent. Dull luster. Hardness 6 to 7. Specific gravity 2.3. Rare. First found with tridymite at Mt. San Cristobal, Mexico.

Anatase, Octahedrite, TiO_2 .

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 1.7844$. Occurs only in small crystals with pyramidal, tabular, or prismatic habit. Figure 42 shows a crystal of the pyramidal type and consists of the modified bipyramids z ($m = 1/3$), and v ($m = 1/7$), unit prism m , prism of the second order a , and the unit bipyramid of the second order e . Over 75 forms have been observed.

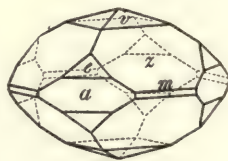


FIG. 42.

Perfect pyramidal and basal cleavages. Hardness 5.5 to 6. Specific gravity 3.81 to 3.95, when heated increases to that of rutile, page 78. Metallic to greasy adamantine luster. Translucent to semi-opaque. Brown, yellow,

low, hyacinth red, indigo blue to black; rarely colorless. Streak white. High indices of refraction, $\omega_{Na} = 2.56$, $\epsilon_{Na} = 2.49$.

TiO₂, may contain some ferric oxide. Reactions same as for rutile, page 78. Occurs as a pseudomorph after titanite and ilmenite. Alters by paramorphism to rutile.

Occurs in cracks and cavities in various silicate rocks, also in gold placers. Found at Tavetsch and St. Gotthard, Switzerland; Fichtelgebirge, Germany, Miask, Ural Mountains; Norway; France; Smithfield, R. I.; and the gold placers of Burke Co., North Carolina.

BADDELEYITE, Brazilite, ZrO₂.

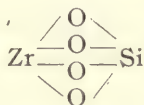
Monoclinic, prismatic class. $a : b : c = 0.9768 : 1 : 1.0475$, $\beta = 98^\circ 40'$. Small, tabular crystals. Colorless, yellow, brown, or black. Hardness 6.5. Specific gravity 5.5 to 5.6. Occurs at Jacupiranga, Brazil; also in the precious stone placers of Rakwana, Ceylon.

RUTILE GROUP

If the formulæ of the dioxides of titanium, tin, lead, and manganese are doubled the analogy between their chemical composition and that of zircon and thorite becomes more apparent. This is clearly seen in the following tabulation:

	$a : c$
RUTILE , TiTiO ₄ .	Ditetragonal Bipyramidal Class 1 : 0.6439
ZIRCON , ZrSiO ₄ .	Ditetragonal Bipyramidal Class 1 : 0.6404
Thorite , ThSiO ₄ .	Ditetragonal Bipyramidal Class 1 : 0.6402
CASSITERITE , SnSnO ₄ .	Ditetragonal Bipyramidal Class 1 : 0.6723
PLATTNERITE , PbPbO ₄ .	Ditetragonal Bipyramidal Class 1 : 0.6764
POLIANITE , MnMnO ₄ .	Ditetragonal Bipyramidal Class 1 : 0.6647

According to von Groth the structural formula of zircon may be written:



By making the proper substitutions in the above, the structural formulae of the various members of this group are easily obtained.

RUTILE, TiTiO₄.

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.6439$. Crystals are common. Usually prismatic or thick columnar, showing vertical striations. The forms commonly observed are the prisms of the first and second orders, unit bipyramid of the first order, and several ditetragonal prisms, especially those where n equals $3/2$, 2, and 3, respectively. A com-

bination, frequently observed, consists of the prisms of the first and second orders, and the unit bipyramid of the first order. Twins occur according to two laws. (1) Twinning plane parallel to the unit bi-

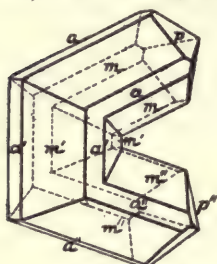


FIG. 43.

pyramid of the second order. Here simple contact twins, the so-called "knee-shaped" crystals, are common. Also polysynthetic twins, cyclic trillings (Figure 43) and so forth. Sixlings according to this law form a closed ring. The various individuals of the sixling lie in one plane. When adjacent faces of the bipyramid of the second order alternate as twinning plane cyclic eightlings result. Such crystals also form a closed ring but the various individuals do

not lie in the same plane. These eightlings are often called rutile rosettes.

(2) The second twinning law is not common. The twinning plane is parallel to a face of the bipyramid of the second order where m equals 3. Also as needle-like crystals, often as inclusions. Compact, disseminated, granular, and as rounded pebbles.

Distinct prismatic and pyramidal cleavages. Conchoidal to uneven fracture. Brittle. Hardness 6 to 6.5. Specific gravity 4.2 to 4.3, ferruginous varieties as high as 5.13. Metallic adamantine luster. Opaque to transparent. Red brown, blood red, cochineal red, black (*nigrine*), and more rarely, yellow, or yellowish brown. Streak yellow or pale brown. Optically positive. Very high indices of refraction: $\omega_{\text{Na}} = 2.616$, $\epsilon_{\text{Na}} = 2.903$.

Ti_2O_4 or TiO_2 . Usually contains from 1.5% to 14% of ferric oxide. Infusible. When fused with sodium carbonate and treated with hydrochloric acid and tin-foil the solution turns violet. Insoluble in acids. Found as a pseudomorph after hematite, and as a paramorph after brookite and anatase, pages 76 and 77.

Most common titanium mineral. Occurs widely distributed. Is found in gneisses, mica schists, syenites, and diorites. To a small extent in granite, granular limestone, and dolomite. The common associates are quartz, feldspar, hematite, and so forth.

Occurs in Norway at Arendal and Kragerö; Sweden; Ural Mountains; Tyrol; St. Gotthard and Binnenthal, Switzerland; Perthshire, Scotland.

The only producing locality in the United States is in Nelson County, Virginia. Rutile also occurs at Graves Mt., Georgia; and Magnet Cove, Arkansas. It is also found in secondary deposits with quartz, tourmaline, gold, diamond, etc.

Used in coloring porcelain yellow and imparting a bluish white tint to artificial teeth. To some extent in special grades of steels and as a mordant in dyeing leather.

ZIRCON, ZrSiO_4 .

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.6404$. Usually in well developed crystals of a prismatic or pyramidal habit. Common forms are the prisms of the first (m) and second (a) orders, the unit (p) and various modified bipyramids of the first order, and also the ditetragonal

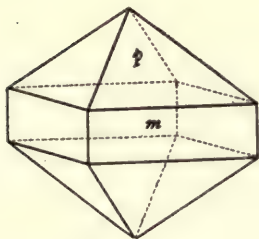


FIG. 44.

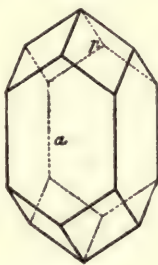


FIG. 45.

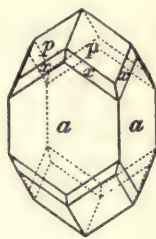


FIG. 46.

bipyramid (x) with the value of n and m equal to 3. Figures 44, 45, and 46 show several common combinations. Twins are rare. Twinning plane parallel to the unit bipyramid of the second order. Also as rounded or angular lumps and grains. Never compact.

Imperfect prismatic and pyramidal cleavages. Conchoidal to uneven fracture. Hardness 7.5. Specific gravity 4.4 to 4.8. Adamantine luster. The commonly observed colors are brown, brownish red, gray, more rarely yellow, green, and colorless. Transparent to opaque. The clear, transparent yellow, red, and brown varieties are *hyacinth*. The term *jargon* is applied to such as are colorless or smoky. Strong double refraction, positive. $\omega_{\text{Li}} = 1.92$, $\epsilon_{\text{Li}} = 1.97$. Colorless Streak.

ZrSiO_4 . Usually a small amount of ferric oxide is present. Infusible. Decomposed by continued action of hot concentrated sulphuric acid. Not acted upon by hydrofluoric acid. *Malakon* is an altered variety of zircon.

A common constituent of the more acid igneous rocks, especially granites and syenites. Also found in crystalline schists, gneisses, and more rarely in granular limestones. Also in secondary deposits with gold, spinel, corundum, etc., thus, on the island of Ceylon; in the auriferous sands of Transylvania; with pyrope in Bohemia and Saxony. Occurs at various places in southeastern Norway, usually in a zircon syenite; Miask, Ural Mountains; Transylvania; etc.

In the United States it is found at various places along the Appalachian Mountains, especially at Litchfield, Me.; Henderson, Iredell, and Buncombe counties, N. C. The occurrence at Zirconia, Henderson Co., N.

C., is the only one of commercial importance in the United States. In 1903 this locality produced 3,000 pounds of zircon valued at \$570.

Zircon is used principally as a source of zirconia, ZrO_2 , which finds limited use in the manufacture of the Nernst lamp glowers. The *hyacinth* varieties are cut for gem purposes. Zircon is also used in the manufacture of extremely delicate and sensitive balances and physical apparatus.

Thorite, Orangite, $ThSiO_4$.

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.6402$. Crystals are similar to those of zircon. Usually compact and disseminated. Conchoidal fracture. Vitreous luster. The term *thorite* is applied to the more or less opaque, dark brown, or black varieties, while the transparent or translucent yellow or orange variety is called *orangite*. The specific gravity of thorite is 4.4 to 4.7 while that of orangite is 5.19 to 5.40.

$ThSiO_4$. Usually more or less impure. Often contains 7 to 10% of water and small amounts of the oxides of calcium, iron, manganese, uranium, and the rare earths. Thorite is believed to be decomposed orangite. Some thorites show a nucleus of fresh orangite.

Occurs in the pegmatites at Brevik, also at Arendal, Norway.

A source of thorium compounds.

CASSITERITE, Tin Stone, Stream Tin, Tin Ore, $SnSnO_4$.

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.6723$. Usually short, thick prismatic crystals, showing the prisms (m and a) and the unit bipyramids (s and e) of the first and second orders in combination, Figure

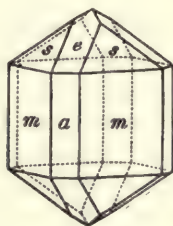


FIG. 47.

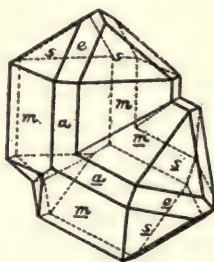


FIG. 48.

47. Sometimes pyramidal habit. Contact and penetration twins very common. Twinning plane parallel to a face of the unit bipyramid of the second order (e). Figure 48 shows a "knee-shaped" contact twin according to

the above law. Also compact and disseminated, reniform, granular, massive, and in rounded grains and pebbles. Concentric and fibrous radial structure is commonly observed.

Imperfect prismatic cleavages. Brittle. Hardness 6 to 7. Specific gravity 6.8 to 7. Adamantine luster, on fracture surface greasy to resinous. Transparent to translucent. Commonly reddish brown, brownish black or pitch black; sometimes red, gray, white or yellow, and rarely colorless. Streak is white to pale brown. Optically positive. High indices of refraction: $\omega_{\text{Na}} = 1.9966$, $\epsilon_{\text{Na}} = 2.0934$.

Several varieties of cassiterite may be distinguished, as follows:

- (1) *Ordinary cassiterite or tin stone*. Crystals and compact masses.
- (2) *Wood tin*. Botryoidal and reniform masses of varying colors, showing an internal radial fibrous structure.
- (3) *Stream tin*. Angular and rounded grains or pebbles in secondary deposits.

Sn_2O_4 , sometimes written SnO_2 . Usually contains a little iron, manganese, silica, and tantalum. Infusible. Yields with difficulty on charcoal a tin coating. Insoluble in acids.

Cassiterite is commonly associated with wolframite, native bismuth, arsenopyrite, molybdenite, scheelite, stannite, chalcopyrite, hematite, chalcocite, magnetite, etc. The minerals found in the gangue include tourmaline, topaz, fluorite, apatite, quartz, and zinnwaldite.

Cassiterite generally occurs in veins cutting granites and eruptive rocks, such as liparites and trachytes. The country rocks adjoining such veins are usually greatly altered and generally show impregnations of cassiterite. Granitic rocks altered in this way are termed *greisen*, while non-granitic rocks are called *twitter*. Deposits of cassiterite are usually considered to be the result of pneumatolytic action. This involves the escape of gases and volatile substances (boron, chlorine, and fluorine), and subsequent action on the country rocks. On account of its great resistance to weathering, cassiterite is also found extensively in secondary deposits.

Occurs in Cornwall, England; Altenberg, Saxony; Joachimsthal, Bohemia; Sweden; Malay Peninsula of Malacca; the islands of Banca and Billiton near Borneo; Tasmania; Bolivia; Mexico; Australia, and China.

The deposits in the Black Hills of South Dakota and the Harney Peak and Nigger Hill districts of Wyoming are the most important in the United States. Other occurrences are at Gaffney, S. C.; Kings Mountains, N. C.;

San Bernardino Co., Cal.; Rockbridge, Va.; Coosa Co., Ala.; El Paso, Texas; Dillon, Montana; and Buck Creek, Alaska.

The most important tin ore. There is practically no cassiterite mined in the United States. The world's supply is obtained principally from the East Indies, Australia, Bolivia, and Cornwall, England.

PLATTNERITE, PbPbO_4 . Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.6764$. Usually massive. Crystals are very rare. Hardness 5 to 5.5. Specific gravity 8.5 to 9.4. Uneven fracture. Iron black in color. Soluble in acids. Streak brown. Opaque. Submetallic luster. Fuses easily, yielding a globule of lead. Occurs at Leadhills, Scotland; Mullan, Idaho.

POLIANITE, MnMnO_4 . Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.6647$. Short thick quadratic crystals. Apparently orthorhombic. Crystals are often very small and poorly developed. Usually in compact, granular and fibrous masses. Sometimes reniform. Steel gray in color. Streak grayish black. Hardness 6 to 6.5. Specific gravity 4.8 to 5. Occurs with manganite and pyrolusite. Often as a pseudomorph after manganite. Changes to pyrolusite. Found at Platten and Schneeberg, Saxony; Johanngeorgenstadt, Bohemia; Cornwall, England.

PYROLUSITE, Black Oxide of Manganese, MnO_2 .

Pseudomorphous after various manganese minerals, hence, often has the crystal form of manganite. It is commonly found compact, fibrous, massive, stalactitic, dendritic, etc.

Hardness 1 to 2.5, soils the fingers. Specific gravity 4.7 to 4.86. Black or bluish black, streak. Black, dark steel gray, or bluish in color. Opaque.

MnO_2 . Usually with small percentages of water and silica. Pyrolusite is not considered an independent species. Infusible, turns brown when heated. Heated in a closed tube, yields oxygen and water. Reacts for manganese in borax bead. Acted upon by hydrochloric acid evolving chlorine. Is formed from manganite, alabandite, rhodocrosite, manganiferous siderite and limonite, etc. Excellent pseudomorphs after manganite, and calcite are sometimes observed. Is commonly found with manganite, psilomelane, hematite, or limonite.

Occurs extensively in Thuringia and the Hartz Mountains, Germany; Bohemia; France; Hungary; Brazil; Russia.

The principal localities in the United States are Crimora district, Augusta Co., Va.; Cave Spring and Cartersville, Ga.; Batesville, Ark.; and Livermore, Alameda Co., Cal.; Brandon, Vt.

In 1905 Virginia produced 3,947 long tons which was practically all of the output of the United States for that year. Considerable quantities are imported annually from Brazil, Russia, Cuba, and Germany.

Pyrolusite is used in the manufacture of chlorine, bromine, oxygen, and spiegeleisen; as a coloring agent in calico-printing and dyeing, glass, pottery, brick, and paints, and as a decolorizer of green glass.

ZINCITE GROUP

This group includes the oxides of cadmium, zinc, manganese, magnesium, and nickel. There are two series, one of which is cubic and the other hexagonal. The most important member of the cubic series is periclase.

CUBIC SERIES

PERICLASE, MgO .	Hexoctahedral Class
MANGANOSITE, MnO .	Hexoctahedral Class
BUNSENITE, NiO .	Hexoctahedral Class
OXIDE OF CADMIUM, CdO .	Hexoctahedral Class

HEXAGONAL SERIES

		$a : c$
Zincite, ZnO .	Dihexagonal Pyramidal Class	$1 : 1.6219$

This group is similar to the sphalerite-wurztite group of the sulphides, see page 32.

PERICLASE, MgO . Cubic. Very small cubical and octahedral crystals. Also in grains. Perfect cubical cleavage. Hardness 6. Specific gravity 3.67 to 3.9. Transparent. Greenish gray to dark green in color. Vitreous luster. Infusible. Powder soluble in acid. Occurs at Mt. Somma, Vesuvius; Nordmark, Sweden.

MANGANOSITE, MnO . Cubic. Extremely small octahedral crystals and compact masses with cubical cleavage. On fresh fracture surface the color is emerald green, which on exposure turns black. Hardness 5 to 6. Specific gravity 5.2. Occurs with periclase at Nordmark, Sweden.

BUNSENITE, NiO . Cubic. Very small octahedral crystals possessing a hardness of 5.5 and a specific gravity of 6.4. Translucent. Green in color. Vitreous luster. Slightly acted upon by acids. Found with annabergite and native bismuth at Johann-georgenstadt, Bohemia.

CADMIUM OXIDE, CdO . Cubic. Usually occurs as a shiny, black coating consisting of octahedrons on hemimorphite at Iglesias, Sardinia.

Zincite, Red Zinc Ore, Red Oxide of Zinc, ZnO .

Hexagonal, dihexagonal pyramidal class. $a : c = 1 : 1.6219$. Natural crystals are rare. Frequently, however, formed in metallurgical processes. Such crystals consist of a pyramid, prism, and basal pinacoid, see Figure 49. Usually as compact, granular or foliated masses.

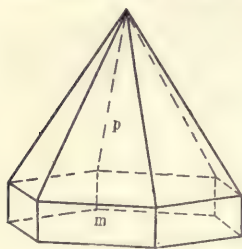


FIG. 49.

Perfect basal cleavage. Brittle. Conchoidal fracture. Hardness 4 to 4.5. Specific gravity 5.4 to 5.7. Subadamantine luster. Blood to hyacinth red in color, also orange, or yellow. Streak reddish yellow. Translucent.

ZnO , may contain as high as 4% of manganese, also small amounts of iron. Infusible. Yields on charcoal a zinc coating and imparts an amethystine color to the borax bead. Soluble in acids.

Occurs extensively in Sussex County, New Jersey, in metamorphic limestones of precambrian age associated with franklinite, rhodonite, sphalerite, rhodocrosite, calcite, hemimorphite, etc. It is an important ore of zinc.

HEMATITE GROUP

This group includes the two very important economic minerals, corundum and hematite. These are the sesquioxides of aluminium and iron, respectively. They crystallize in the hexagonal system.

CORUNDUM, Al_2O_3 .

Ditrigonal Scalenohedral Class $a : c = 1 : 1.364$

HEMATITE, Fe_2O_3 .

Ditrigonal Scalenohedral Class $a : c = 1 : 1.359$

Of these minerals hematite is by far the more important, commercially.

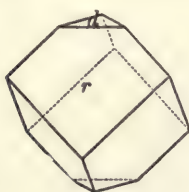


FIG. 50.

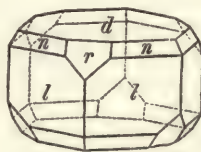


FIG. 51.

CORUNDUM, Sapphire, Ruby, Emery, Al_2O_3 .

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.364$. Well developed crystals, often rather large, are common. The habit may be pyramidal, rhombohedral (Figure 50), prismatic (Figure 51), or tabular. The common forms are the prism of the second order (l), unit rhombohedron (r), bipyramid of the second order (n) with m equal to $4/3$, and

the basal pinacoid (*d*). Often several modified bipyramids of the second order are present and then the crystals assume a more or less barrel shape. Large crystals are sometimes rough and rounded. Penetration and polysynthetic twins with the twinning plane parallel to the unit rhombohedron. The basal pinacoid often shows triangular striations. Also occurs massive with a nearly rectangular parting or pseudo-cleavage.

Conchoidal fracture. Rhombohedral and basal partings. The hardness is 9. Specific gravity 3.9 to 4.1. Colorless, blue, red, brown, yellow, violet, etc. Sometimes multicolored. Transparent to translucent, or vitreous luster. Optically negative, $\omega_{Li} = 1.769$, $\epsilon_{Li} = 1.760$.

Al_2O_3 . Crystals are usually quite pure. Small amounts of ferric oxide may be present as a pigment. Emery generally contains considerable magnetite, Fe_3O_4 .

Three varieties may be distinguished, as follows:

(1) *Sapphire* and *ruby*. This is the gem variety and includes the beautifully colored, transparent stones. If blue it is the *sapphire*; red, the *ruby*; green, the *oriental emerald*; yellow, the *oriental topaz*; and violet, the *oriental amethyst*.

(2) *Corundum* or *adamantine spar*. Here are placed crystals and masses with dull colors, usually blue, gray, red, brown, or black.

(3) *Emery*. This is a mixture of corundum, magnetite, hematite, and quartz. It was first considered an iron ore. The admixture may be as high as 40%. The hardness is, hence, considerably lower than that of the other varieties. Dark gray to black in color.

Corundum occurs usually disseminated in crystalline limestone and dolomite, gneiss, mica schist, chlorite schist, peridotite, granite, nepheline syenite, gabbro, norite, etc.

The gem varieties are found principally in placer deposits in Ceylon, Burma, Hindustan, Siam, China, Ural Mountains; also near Helena, Montana, and in North Carolina. Rubies of a fine and clear quality are very expensive, being worth as much as \$1,500 per carat. Sapphires are less expensive, a one carat stone costing anywhere from \$6 to \$125, depending upon the quality.

Corundum proper is found in extensive deposits associated with peridotite in North and South Carolina, and Georgia; at Raglan and elsewhere in Renfrew county, Ontario, in nepheline syenite; also in Westchester county, New York; Chester county, Pennsylvania; and Chester, Massachusetts.

Most of the world's supply of emery is obtained from the islands of Naxos and Samos in the Grecian archipelago and from Asia Minor. On Naxos and Samos it occurs in crystalline limestones and schists. It is also found in the Ural Mountains and Saxony.

In the United States, Chester, Mass., and Peekskill, N. Y., are the only localities producing emery. At Chester, Mass., the emery occurs in amphibolite schists associated with chlorite and margarite; at Peekskill, N. Y., in peridotite.

Sapphire and ruby are used extensively for gem purposes and as watch jewels; massive corundum and emery as abrasives.

HEMATITE, Specularite, Specular Iron Ore, Red Iron Ore, Fe_2O_3 .

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.359$. Crystals are rather common, either pyramidal, thin or thick tabular, rhombohedral, or more rarely prismatic in development. Figure 52 shows a combination in which (r) is the unit rhombohedron, (r') the modified rhombohedron with the coefficient m equal to $1/4$, and (p) the hexagonal bipyramid of the second order with m equal to $4/3$. A comparatively large number of forms has been observed on hematite. Tabular crystals are often arranged parallel or in rosettes and are then called "iron roses."

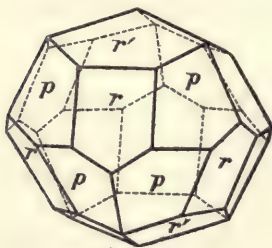


FIG. 52.

Two twinning laws have been noted. (1) Twinning plane parallel to the basal pinacoid. (2) The unit rhombohedron acts as the twinning plane. This law is not common. The basal pinacoid is sometimes striated, due to polysynthetic twinning according to the second law. Occurs more abundantly in compact, granular, micaceous, earthy, columnar, fibrous, botryoidal, reniform, and stalactitic masses.

No cleavage. Owing to polysynthetic twinning some crystals show a perfect parting parallel to the unit rhombohedron. Conchoidal to uneven fracture. Hardness 5.5 to 6.5, earthy varieties are very soft. Specific gravity 4.9 to 5.3, crystals usually about 5.25. The luster is metallic, splendid, or dull. Opaque, except in very thin scales. Steel gray to iron black in color, sometimes with beautiful tarnish colors. Thin scales are blood red to yellow red in transmitted light. The earthy variety is red in color. The streak is cherry red or reddish brown. Sometimes slightly magnetic owing to the presence of a small amount of magnetite, Fe_3O_4 .

Fe_2O_3 . May contain as high as 7% of titanium dioxide, also ferrous oxide, magnesium oxide, phosphoric acid, silica, clay, etc. Infusible. Heated on charcoal it becomes magnetic. Powder is slowly soluble in acids. Occurs as a pseudomorph after calcite, siderite, pyrite, and magnetite.

There are several varieties of hematite:

(1) *Specularite* or *specular iron ore*. This includes crystals, mica-

ceous, and granular masses with a metallic or splendid luster. Usually dark steel gray or black in color.

(2) *Compact or red hematite*. Massive. Submetallic to dull luster. Iron black or brownish red in color. Often shows radial fibrous structure. Also reniform.

(3) *Red ocher, reddle, or red clay*. A red earthy variety. Very soft. Dull luster. Usually contains considerable clay.

(4) *Argillaceous hematite, red clay ironstone*. Hard, and compact. Brownish black, reddish brown, or deep red in color. Contains much clay, sand, jasper, etc.

(5) *Oolitic iron ore*. Hematite with oolitic structure. Often fossiliferous.

(6) *Martite*. Hematite occurring in octahedrons as a pseudomorph after magnetite.

Hematite is the most important iron ore. It occurs (1) as independent deposits, sometimes of great thickness and extent, in rocks of varying ages. (2) As an accessory mineral in many of the igneous rocks such as granites, syenites, etc. (3) In cracks and crevices, usually with quartz. (4) As an inclusion in many minerals, for example, feldspar, heulandite, and carnallite. (5) As a sublimation product in lavas. Thus on Vesuvius, Aetna, etc. (6) Sometimes the result of contact metamorphism.

Excellent crystals occur on the island of Elba in the Mediterranean Sea; Binnenthal, Tavetsch, and St. Gotthard (iron roses), Switzerland; Arendal, Norway; Langban and Nordmark, Sweden.

Enormous deposits of hematite occur in the rocks, chiefly of Huronian and Archean age, in the Lake Superior region of Northern Michigan, Wisconsin, Minnesota, and Canada. Six ranges or districts may be mentioned, viz: *Marquette* in Michigan, *Menominee* and *Gogebic* in Michigan and Wisconsin, *Mesabi* and *Vermilion* in Minnesota, and the *Michipicoten* in Ontario, Canada. In 1907 this region* produced 41,638,744 long tons of hematite ore which contained from about 45 to 60% of iron and 9 to 13% moisture. Oolitic hematite is found in beds of considerable thickness in the Clinton formation of Lower Silurian age. At Clinton, N. Y., and Birmingham and vicinity in Alabama large quantities of this variety of hematite are mined annually. Oolitic hematite is also found in Pennsylvania, Wisconsin, and Canada. Martite occurs in Saxony, Brazil, and in the Ural Mountains; also in the Marquette iron district, Michigan; Millard Co., Utah; Monroe Co., N. Y.; Chittenden, Digby Co., Nova Scotia; and Mexico.

* Not including the Michipicoten district.

Hematite is mined in a comparatively large number of states as is shown by the following table giving the production for 1907:

Minnesota	28,969,658	long tons
Michigan	11,830,342	long tons
Alabama	3,144,011	long tons
Wisconsin	804,454	long tons
Montana, Nevada, New Mexico, Utah, and Wyoming.....	608,056	long tons
Tennessee	269,182	long tons
New York	140,101	long tons
Georgia	106,885	long tons
Virginia	89,867	long tons
Missouri	42,527	long tons
Kentucky, Maryland, West Virginia	36,000	long tons
Pennsylvania	19,403	long tons
Total	46,060,486	long tons

Hematite is the chief source of the iron of commerce. About 90% of the iron ore mined annually is hematite.

CUPRITE GROUP

The oxides of lead and copper are placed here. No definite relationship between the members of this group has, as yet, been pointed out.

MASSICOT, PbO. Orthorhombic, Bipyramidal Class $a : b : c = 0.6706 : 1 : 0.9764$
CUPRITE, Cu₂O. Cubic, Pentagonal Icositetrahedral Class.

PARAMELACONITE, CuO. Tetragonal, Bipyramidal Class $a : c = 1 : 1.6534$

MELACONITE, CuO. Monoclinic, Prismatic Class $a : b : c = 0.6711 : 0.9129, \beta = 99^\circ 32'$
 (*Tenorite*)

Cuprite is the most important mineral of this group.

MASSICOT, PbO. Natural crystals have not been observed. Found as scaly, earthy, and compact masses. Artificial crystals are orthorhombic. Yellowish or reddish in color. Greasy luster. Occurs in Mexico. Rare.

CUPRITE, Ruby Copper Ore, Red Oxide of Copper, Cu₂O.

Cubic, pentagonal icositetrahedral class. Crystals are common. The octahedron and rhombic dodecahedron are the most common forms. They occur either independently or in combination. Other forms are the cube,

trigonal and tetragonal tristoctahedrons ($m=2$). The pentagonal icositetrahedron is sometimes observed. Also compact, granular, earthy, and in fine, slender crystal-aggregates (*chalcotrichite*).

Octahedral cleavage, not very pronounced. Conchoidal to uneven fracture. Brittle. Hardness 3.5 to 4. Specific gravity 5.7 to 6.15. Metallic adamantine luster on crystal and fresh fracture surfaces, also submetallic or earthy. Cochineal red to almost black. A brick red, earthy variety which is sometimes mixed with hematite or limonite, is called *tile ore*. Semi-transparent to almost opaque. Streak brownish red to dirty brown, shiny. The streak of chalcotrichite is carmine red. High index of refraction: $n_{Li} = 2.849$.

Cu_2O . Usually quite pure. Colors flame green. Heated on charcoal turns black and yields easily a globule of copper. Soluble in acids and ammonium hydroxide. Alters readily to malachite, azurite, tenorite, or copper. Pseudomorphs of malachite after cuprite are quite common.

Cuprite is usually the result of the oxidation of copper minerals. It occurs at Chessy, France, in large crystals sometimes partially or completely altered to malachite; also at Cornwall, England; Dobschau, Hungary; Chile; Peru; Bolivia; Southern Australia; Ural Mountains; etc.

In the United States it is found with other copper minerals at Bisbee, Clifton, and elsewhere in Arizona; Sommerville, N. J.; Lebanon Co., Pa.; Lake Superior Copper district.

An important ore of copper.

PARAMELACONITE, CuO . Tetragonal. Occurs in horizontally striated pyramidal crystals. No cleavage. Hardness 5. Specific gravity 5.83. Brilliant luster. On crystal faces is purplish black in color, on fracture surfaces pitch black. Found at the Copper Queen mine, Arizona.

MELACONITE, Tenorite, CuO .

Monoclinic. Small, scaly crystals of apparently hexagonal outline occur on Vesuvius. Commonly found as a coating on copper minerals. Also massive. Steel gray to black in color. The crystals are termed *tenorite*, the earthy masses *melaconite*. Specific gravity of the crystals is 5.82, of the masses 6.25. Hardness 3 to 4. Occurs with native copper in the Lake Superior Copper district; Ducktown, Tenn.; and in various copper mines in Arizona.

2. HYDROXIDES

OPAL, $SiO_2 \cdot x H_2O$.

Amorphous. Usually occurs compact, in veins or masses of irregular outline. Sometimes stalactitic or reniform. Also loose and more or less earthy.

Conchoidal fracture is very characteristic. Hardness 5.5 to 6.5, but in earthy varieties may be as low as 1. Specific gravity 2.1 to 2.3, when pure 2.15 to 2.2. Vitreous, dull, or greasy luster. Transparent to opaque. Streak white. The color varies greatly, may be white, yellow, brown, red, green, gray, etc. Often a play of colors is to be observed. This is due to fine cracks filled with material possessing a slightly different index of refraction than the original substance, and perhaps also to an unequal distribution of the water content. Low index of refraction, $n_{Li} = 1.4347$ to 1.4555. Sometimes shows anomalous double refraction.

$\text{SiO}_2 \cdot x \text{H}_2\text{O}$. The amount of water may vary from 1 to 21%, is, however, usually between 3 and 13%. May also contain small amounts of the oxides of calcium, iron, magnesium, aluminium, and sodium, as well as bitumen, etc. Many opals are to be considered as dried and hardened gelatinous silica. Yields water when heated in a closed tube. Infusible. Soluble in hot caustic potash or soda.

There are several varieties of opal:

(1) *Precious opal*. Usually bluish or yellowish white in color with excellent play of colors. Used as a gem.

(2) *Fire opal*. Yellow to red in color. Semi-transparent.

(3) *Common opal*. Translucent to opaque. Shows many colors. When milk-white, yellowish, bluish, or greenish it is called *milk opal*; with a resinous luster and either wax, honey, or ocher yellow in color, it is *resin opal*. Wood petrified by opaline material is called *wood opal*. Precious opal which has become cloudy and white by the loss of water is termed *hydrophane*.

(4) *Opal jasper* is red, reddish brown, or brownish yellow. It possesses a resinous luster. Resembles jasper.

(5) *Hyalite*. Colorless and transparent masses of irregular outline. Looks like drops of molten glass.

(6) *Silicious sinter*, *Geyserite*, *Fiorite*. These include the opaline material deposited from the waters of hot springs. May be porous, compact, fibrous, stalactitic, botryoidal, etc. Transparent to opaque. Grayish, whitish, or brown in color. Sometimes has a pearly luster.

(7) *Tripolite*, *Diatomaceous or infusorial earth*. Consists of the silicious remains of diatoms, radiolaria, etc. Is usually porous, earthy, and chalk-like in appearance. Light in weight.

Opal may result (1) from the decomposition of silicate minerals and is then found in cracks and cavities in such igneous rocks as trachytes, porphyries, etc. (2) As a deposit from hot springs. (3) By the accumulation of hard, silicious remains of various microscopic organisms. (4) By the

accumulation, partial solution and subsequent sodification of silicious matter derived from radiolaria, infusoria, sponge spicules, etc.

Precious opal occurs in decomposed trachyte at Czerwenitz, Hungary; Querétaro and Zimapan, Mexico; Gem City, and Morrow Co., Washington; Opaline, and Latah Co., Utah, etc. Hyalite occurs at Schemnitz, Hungary; Bohemia; Mexico; also in New Jersey and Connecticut. Common opal is rather abundant in Pennsylvania, Idaho, Colorado, California, etc. Geyserite is found in the Yellowstone Park and silicious sinter at the Steamboat Springs, Nevada. Infusorial earth occurs in considerable deposits at Dunkirk, Md.; Richmond, Va.; Drakesville, N. J.; Socorro, N. M.; also in California, Missouri, New York, Georgia, Connecticut, etc., etc. In 1907 the production of infusorial earth in the United States was valued at \$104,406.

Precious and fire opals are used for gem purposes; wood opal for ornamental purposes. Infusorial earth is used largely in polishing powders, scouring soaps, as an absorbent of nitroglycerine, a non-conductor of heat, in fire-proof cement, soluble glass, water filters, and as an adulterant of flour.

SASSOLITE GROUP

On account of their striking chemical similarity sassolite and gibbsite are sometimes considered isomorphous even though they do not crystallize in the same system.

SASSOLITE, $B(OH)_3$. Triclinic, Pinacoidal Class

a	:	b	:	c		α		β		γ
1.7329	:	1	:	0.9228		92°30'		104°25'		89°49'

Gibbsite, $Al(OH)_3$. Monoclinic, Prismatic Class

1.7089	:	1	:	1.9184		94°31'
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SASSOLITE, Boric Acid, $B(OH)_3$.

Triclinic, pinacoidal class. Usually in fine scaly or fibrous crystals having a prism angle of 118°9'. Sometimes stalactitic. May be colorless, white, or yellow. Pearly luster. Greasy feel. Hardness 1. Specific gravity 1.45. Sour taste. Reacts for boron. Soluble in water.

Occurs as a sublimation product on the island of Vulcano in the Mediterranean Sea; in the vapors escaping from the hot springs in Tuscany; also at Clear Lake, California.

A source of boric acid and borax. Large quantities are obtained from the hot springs of Tuscany. The escaping vapors are conducted into water. The boric acid is absorbed and sassolite deposited. Boric acid is used as an antiseptic, preservative of food, in the manufacture of enamels and glazes for pottery, etc.

Gibbsite, Hydrargillite, $\text{Al}(\text{OH})_3$.

Monoclinic, prismatic class. Rarely in tabular crystals with an hexagonal outline. Usually stalactitic and mammillary. Surface is generally smooth. Internal structure usually fibrous. Basal cleavage. White, grayish, greenish, or reddish in color. Hardness 2.5. Specific gravity 2.3 to 2.4. Pearly to vitreous luster. Translucent, crystals are sometimes transparent. Streak white. Argillaceous odor when breathed upon.

Infusible. Reacts for aluminium with cobalt solution. Soluble in hydrochloric or sulphuric acids. Yields water in a closed tube.

Gibbsite is of limited occurrence. It is usually found with bauxite, thus in Saline and Pulaski counties, Arkansas; also in Floyd, Bartow, and Walker counties, Georgia. With limonite in Dutchess and Orange counties, New York.

MANGANITE GROUP

The hydroxides of aluminium, iron, and manganese, which conform to the general formula $\text{M}'''\text{O.OH}$, are placed here. These minerals crystallize in the orthorhombic bipyramidal class.

	a	b	c
Diaspore, AlO.OH.	0.9372	1	0.6038
MANGANITE, MnO.OH.	0.8439	1	0.5447
GOETHITE, FeO.OH.	0.9163	1	0.6008

A comparison of the ordinary axial ratios of these minerals shows considerable variation. However, on account of the similarity of form, cleavage, etc., diaspore, manganite, and goethite are to be considered isomorphous. The topical axes show a much closer agreement than is noted above.*

Diaspore, AlO.OH .

Orthorhombic, bipyramidal class. $a : b : c = 0.9372 : 1 : 0.6038$. Broad columnar and tabular crystals. Flattened parallel to the brachypinacoid. Vertically striated. Crystals not common. Usually in thin scaly and broad fibrous aggregates.

Perfect brachypinacoidal cleavage. Brittle. Hardness 6 to 7. Specific gravity 3.3 to 3.5. Colorless, pale yellow, violet blue, and brown. Pearly luster on cleavage surfaces, otherwise vitreous. Transparent to translucent. Excellent trichroism.

AlO.OH . In closed tube yields water. Gives a blue color when heated with cobalt solution. Infusible. After strong ignition it is rendered soluble in sulphuric acid.

*Kraus and Mez, Ueber Topischen Axenverhältnisse, Zeitschrift für Krystallographie, etc., 1901, 34, 389 to 396.

Commonly found with corundum or emery, dolomite, cyanite, margarite, etc. Occurs at Schemnitz, Hungary; Ural Mountains; various places in Tyrol; on the island of Naxos, Grecian archipelago; Chester, Mass.; Unionville, Pa.; Franklin, Macon Co., N. C., etc. Not very common.

MANGANITE, MnO.OH .

Orthorhombic, bipyramidal class. $a : b : c = 0.8439 : 1 : 0.5447$. Commonly as long or short prismatic crystals. Often with deep vertical striations. Sometimes arranged in groups or bundles. The forms usually observed are the unit prism, unit macrodome, and the basal pinacoid. A comparatively large number of forms has been observed. Also radiated and columnar. Rarely granular or stalactitic.

Perfect brachypinacoidal cleavage. Uneven fracture. Brittle. Hardness 3.5 to 4. Specific gravity 4.2 to 4.4. When fresh, manganite possesses a submetallic luster, an iron black color, and reddish brown to brown black streak. If more or less decomposed, it is steel gray in color with a black streak and metallic luster.

MnO.OH . Yields water when heated above 200°C . • Reacts for manganese with borax bead. Soluble in concentrated hydrochloric acid with an evolution of chlorine. Occurs as a pseudomorph after calcite.

Alters easily to pyrolusite and, hence, is not often found fresh. Commonly associated with barite, calcite, siderite, pyrolusite and other manganese minerals. Excellent crystals at Ilfeld, Hartz Mountains; Ilmenau, Thuringia; Wittichen in the Black Forest, Baden; Jackson mine, Marquette Co., Mich.; Douglas Co., Colo.; various places in Nova Scotia and New Brunswick.

With pyrolusite it is used in the preparation of oxygen and chlorine.

GOETHITE, FeO.OH .

Orthorhombic, bipyramidal class. $a : b : c = 0.9163 : 1 : 0.6008$. Crystals are generally small. May be prismatic, needle-like, tabular, or scaly. The most commonly observed forms are the unit and macro- ($n=2$) prisms, brachy, macro and basal pinacoids, macrodome ($m=4$), and the unit and macro ($n=2$) bipyramids. Also occurs in scaly, fibrous and velvety crusts. Massive and stalactitic. Perfect brachypinacoidal cleavage. Hardness 5 to 5.5. Specific gravity 4 to 4.4. Subadamantine luster. Color yellow, red, dark brown, or nearly black. Streak yellow or yellow brown.

FeO.OH . Usually contains some silica and manganese. On heating yields water. Soluble in hydrochloric acid. Thin splinters fuse to a black magnetic mass. Pseudomorphs after pyrite. Alters to limonite or hematite. Generally found with hematite or limonite. Commercially, it is classed with limonite under the heading of brown hematite. It is of comparatively limited occurrence. Found at Příbram, Hungary; Siegen, Nassau, Germany; Cornwall, England; Negaunee, Mich.; Easton, Pa.; Pike's Peak district, Colo.; various places in Minnesota.

Used as an ore of iron.

BAUXITE GROUP

Here are placed the hydroxides conforming to the formula $M'''_2O(OH)_4$ in which the metal may be aluminium, iron, cobalt, or nickel. The members of this group do not occur crystallized.

BAUXITE, $Al_2O(OH)_4$.

XANTHOSIDERITE, $Fe_2O(OH)_4$.

WINKLERITE, $(Co,Ni)_2O(OH)_4$.

BAUXITE, Beauxite, $Al_2O(OH)_4$.

Crystallization unknown. Usually massive, pisolitic or oolitic, also earthy resembling clay. Sometimes disseminated in concretionary grains.

May be white, brown, yellow, or reddish. The color is often irregularly distributed. Hardness 1 to 3. Specific gravity 2.55. Argillaceous odor. Variable streak.

$Al_2O(OH)_4$. In general the composition varies greatly, showing about 50 to 70% of aluminium oxide, 3 to 35% ferric oxide, 12 to 40% water, 2 to 30% silica, 3% titanium oxide, also carbon dioxide, phosphoric acid, manganese, etc. Infusible. Yields water in a closed tube. Heated with cobalt solution it turns blue. Soluble with difficulty in hydrochloric acid.

Bauxite has resulted from the decomposition of feldspathic rocks, such as granites, gneisses, diorites, basalts, etc. It is the principal constituent of *laterite*, which is quite abundant in tropical regions. Also found in nodules, grains, and in pockets of irregular shape in limestones and dolomites. Such occurrences are thought to be the result of deposition, perhaps from hot solutions.

Important deposits occur at Baux, near Arles, France; Vogelsberg, Nassau, Germany; also in Carniola and Ireland. In the United States large deposits are found in a belt extending from Jacksonville, Alabama to Cartersville, Georgia; Pulaski and Saline counties, Arkansas; and near Silver City, New Mexico. In 1907 the United States produced 97,776 long tons of bauxite valued at \$480,330.

Bauxite is used in the manufacture of aluminium, alum, and various refractory products.

XANTHOSIDERITE, $Fe_2O(OH)_4$. Occurs in radial fibrous aggregates of a golden yellow to brownish red color. Found with manganese minerals at Ilmenau, Thuringia.

WINKLERITE, $(Co,Ni)_2O(OH)_4$, is compact and possesses a bluish or violet color. Found in Spain. Rare.

LIMONITE, Brown Hematite, Bog Iron Ore, $\text{Fe}_4\text{O}_3(\text{OH})_6$.

Crystallization is supposed to be orthorhombic. Nearly always in compact, porous, or earthy masses. Often stalactitic, botryoidal, or mammillary. Radial fibrous structure and black varnish-like surfaces are characteristic features. Also concretionary.

Physical properties vary greatly with the variety. Conchoidal or earthy fracture. Hardness 1 to 5.5. Specific gravity 3.4 to 4. May be brown, yellow brown, brown black, or black. Streak is always yellow brown.

$\text{Fe}_4\text{O}_3(\text{OH})_6$. Often more or less impure. May contain silica, clay, manganese, phosphorous, and organic matter. Yields water in a closed tube. Thin splinters fuse to a magnetic globule. Soluble in hydrochloric acid, often yielding a gelatinous residue. Common as a pseudomorph after iron minerals, especially pyrite, marcasite, siderite, etc.

Several varieties of limonite have been distinguished, as follows:

(1) *Compact limonite*. This includes the compact massive, stalactitic, botryoidal, and other varieties which often possesses a radial fibrous structure and smooth varnish-like surfaces.

(2) *Ochreous limonite*. Here are placed the earthy, yellow or brownish varieties which may be quite impure, on account of an admixture of clay and sand.

(3) *Bog iron ore*. Found in marshy and swampy places. More or less loose and porous in texture and may contain organic remains.

(4) *Brown clay ironstone*. Usually in compact masses. Often impure, may contain clay or sand. Also concretionary and nodular, pisolitic or oolitic.

Limonite is the usual decomposition product of iron minerals, resulting through the action of water, carbon dioxide, humus acid, oxygen, etc. Hence it is found very extensively and usually in association with such minerals as pyrite, hematite, magnetite, siderite, etc.; also with many of the rock-forming minerals which contain iron in small quantities as the amphiboles, pyroxenes, etc. The so-called *residual* limonite may be the result of (1) the decomposition of veins containing iron disulphide, or (2) from the weathering of ferruginous rocks. Residual limonite is usually associated with slates, schists, or limestones. It occurs rather extensively in the United States in a belt extending from Vermont to Alabama. Limonite is also found in considerable quantities in Texas, Iowa, Wisconsin, Minnesota, and Oregon. Likewise in Bavaria, Hartz Mountains, Scotland, Sweden, etc.

An iron ore; used also as yellow ocher, burnt umber, burnt sienna, etc., in paint. In 1908 the output of limonite* in the United States was 2,620,390

* This also includes goethite, see page 93.

long tons. This was about 7% of the iron ore mined that year. This supply was obtained principally from Alabama, Virginia, West Virginia, Tennessee, etc.

BRUCITE GROUP

This group embraces the hydroxides of magnesium, manganese, and iron which conform to the formula $M''(\text{OH})_2$. The members of this group crystallize in the hexagonal system.

		$a : c$
Brucite , $\text{Mg}(\text{OH})_2$.	Ditrigonal Scalenohedral Class	1 : 1.5208
MANGANOBUCITE , $(\text{Mg}, \text{Mn})(\text{OH})_2$.	Ditrigonal Scalenohedral Class	?
FERROBRUCITE , $(\text{Mg}, \text{Fe})(\text{OH})_2$.	Ditrigonal Scalenohedral Class	?
PYROCHROITE , $\text{Mn}(\text{OH})_2$.	Ditrigonal Scalenohedral Class	1 : 1.4002

Of these minerals brucite is the most important.

Brucite, $\text{Mg}(\text{OH})_2$.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.5208$. Crystals are generally broad tabular. Commonly found in foliated masses; sometimes fibrous and scaly. Fibers are elastic.

Perfect basal cleavage. Hardness 2 to 2.5. Specific gravity 2.3 to 2.4. Thin plates or scales are flexible. Pearly to vitreous luster. Transparent to translucent. Color is white, gray, blue, or green. White streak. Looks like gypsum and talc.

$\text{Mg}(\text{OH})_2$. If manganese or iron replace a portion of the magnesium *manganobrucite* and *ferrobrucite* result. Infusible. Heated with cobalt solution it turns pink. Soluble in hydrochloric acid. Decomposes to hydro-magnesite.

Found with serpentine and other magnesium minerals, also in limestones. Occurs at Hoboken, N. J.; Brewster, N. Y.; Texas, Pa.; Predazzo, Tyrol, etc.

PYROCHROITE, $\text{Mn}(\text{OH})_2$, is isomorphous with brucite. Usually in granular or foliated masses. Pearly luster. When fresh is white but darkens on exposure. Thin scales are translucent. Occurs with magnetite at Pjasberg, Sweden; also at Franklin Furnace, N. J.

MOLYBDITE, Molybdic Ocher, $\text{Mo}_3\text{Fe}_2\text{O}_{12} \cdot 7\frac{1}{2}\text{H}_2\text{O}$.

Molybdate was formerly considered MoO_3 . Schaller has, however, shown that its composition may be expressed by the formula $\text{Fe}_2\text{O}_3, 3\text{MoO}_3, 7\frac{1}{2}\text{H}_2\text{O}$.

Fibrous structure, often arranged in radial aggregates. Yellow in color. Silky luster. Yields water in a closed tube and turns dark olive green. Becomes paler on continued heating. Soluble in hydrochloric acid, with difficulty in ammonium hydroxide.

Occurs at Westmoreland, N. H.; Telluride, Colo.; Renfrew Co., Ontario; and in California.

OXYSULPHIDES

There are only two oxysulphides which occur in nature, kermesite $\text{Sb}_2\text{S}_2\text{O}$, and voltzite, $\text{Zn}_5\text{S}_4\text{O}$. Only kermesite will be described.

KERMESITE, Pyrostibite, Red Antimony, $\text{Sb}_2\text{S}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 3.9650 : 1 : 0.8535$, β is approximately 90° . Acicular crystals, also hair-like fibers, radial fibrous aggregates, and disseminated. Color is cherry red. Adamantine luster. Translucent, almost opaque. Brownish red streak. Hardness 1 to 1.5. Specific gravity 4.5 to 4.6. Blowpipe reactions same as for stibnite. Usually with stibnite and native antimony. Some localities are Příbram, Bohemia; Bräunsdorf, Saxony; Allemont, Dauphiné; in large quantities at Pereta, Tuscany; South Ham, Quebec, Canada; also York Co., New Brunswick.

IV. HALOIDS

1. SIMPLE HALOIDS

Here are placed the simple compounds of the halogen elements, chlorine, bromine, fluorine, and iodine, with the various metals. A few of the compounds contain water of crystallization.

HALITE GROUP

This group embraces the haloids of potassium, sodium, silver, and ammonium. They all crystallize in the cubic system. There is, however, considerable difference in symmetry to be observed between the various members of the group.

Sylvite, KCl.	Pentagonal Icositetrahedral Class
SAL AMMONIAC, NH_4Cl .	Pentagonal Icositetrahedral Class
HALITE, NaCl.	Hexoctahedral Class
Cerargyrite, AgCl.	Hexoctahedral Class
EMBOLITE, $\text{Ag}(\text{Cl}, \text{Br})$.	Hexoctahedral Class
BROMYRITE, AgBr.	Hexoctahedral Class
IODOBROMITE, $\text{Ag}(\text{Cl}, \text{Br}, \text{I})$.	Hexoctahedral Class
MIERSITE, AgI.	Hextetrahedral Class

The compound AgI is dimorphous. The second modification is *iodyrite* which crystallizes in the dihexagonal pyramidal class, $a : c = 1 : 0.8196$. Halite is, by far, the most important mineral in this group.

Sylvite, KCl.

Cubic, pentagonal icositetrahedral class. Crystals generally show a combination of the cube and octahedron. Gyroidal hemihedrism is revealed by etch figures. Usually in granular and compact masses.

Perfect cubical cleavage. Conchoidal fracture. Hardness 2 to 2.5. Specific gravity 1.9 to 2. Colorless; due to inclusions may be bluish, yellowish or red. Transparent to translucent. Colorless and transparent crystals from Stassfurt, Germany, are termed *hövellite*. Due to the presence of magnesium chloride, it may be deliquescent. Disagreeable bitter taste.

KCl. Sometimes almost pure, but may contain chlorides of sodium and magnesium. Colors flame violet. Easily soluble in water. Fuses and volatilizes easily.



Mixed with halite and kainite, it occurs in large quantities in the salt deposits of Stassfurt, Germany. Also at Kalusz, Galicia, Austria; Berchtesgaden, Bavaria; Mayo mine in the Salt Range in India; and on Mt. Vesuvius.

Sylvite is of importance in the conversion of Chile saltpeter, NaNO_3 , into the more valuable potassium nitrate according to the following reaction: $\text{KCl} + \text{NaNO}_3 = \text{KNO}_3 + \text{NaCl}$. It is also used as a fertilizer.

SAL AMMONIAC, NH_4Cl .

Cubic, pentagonal icositetrahedral class. Crystals are rare. Often greatly misshapen. Artificial crystals sometimes show a pentagonal icositetrahedron. Usually as fibrous, powdery, or stalactitic masses, also in crusts.

Imperfect octahedral cleavage. Conchoidal fracture. Hardness 1.5 to 2. Specific gravity 1.5 to 1.6. Colorless, yellow, or brown. Pungent taste. Transparent to translucent. Vitreous luster.

NH_4Cl may contain small amounts of ferric chloride. Easily soluble in water. Volatilizes readily and completely. Boiled with potassium hydroxide, it evolves ammonia fumes.

Occurs as a sublimation product about various volcanoes, thus at Aetna, Vesuvius, Kilauea, etc. Also near burning coal-beds and in guano deposits. The neutral compound does not occur abundantly enough to be of commercial importance.

HALITE, Common Salt, Rock Salt, NaCl .

Cubic, hexoctahedral class. Crystals are generally cubes, rarely in combination with the octahedron, tetragonal trisoctahedron, or the tetrahexahedron. Crystals are sometimes skeletal or hopper-shaped. Usually as compact, fibrous, or granular aggregates. Also as a fibrous efflorescence, especially in arid regions; stalactitic.

Excellent cubical cleavage. Conchoidal fracture. Brittle. Hardness 2 to 2.5. Specific gravity 2.1 to 2.3. When pure colorless, due to impurities reddish, blue, gray, greenish, or black. The admixtures may be ferric oxide, hydrocarbons, bitumen, anhydrite, or clay. Easily soluble in water (1 part in 2.8 parts of water). Saline taste. Vitreous luster. $n_{\text{Na}} = 1.5442$. Transparent to translucent.

NaCl . Sometimes very pure, (Petite Anse, La., 98.88% and Holston Valley, Va., 99.55% NaCl). May contain varying percentages of calcium and magnesium chlorides, also admixtures of gypsum, anhydrite, organic matter, clay, occluded liquids and gases, etc. Colors flame yellow. Volatilizes easily before the blowpipe.

Salt occurs widely distributed. There are four methods of occurrence: (1) *Deposits*, often of great thickness and extent; (2) *Efflorescence*; (3) *Sublimation product*; (4) *In solution*.

(1) *Deposits*. Here the salt is generally associated with gypsum or anhydrite, and is found in sedimentary rocks of all ages. Many deposits

are very extensive and of great thickness, thus, the thickness in various places in Central New York is 350 feet; in Michigan 400 feet; Stassfurt, Germany, 1,200 feet; Petite Anse, La., 1,756 feet; and Sperenberg, Germany, 4,200 feet.

Some of the more noted salt deposits are at Wieliczka, Galicia; Parajd, Transylvania; Bochnia and Kalusz, Galicia; Berchtesgaden, Bavaria; Hall, Austria; Stassfurt and Sperenberg, North Germany; Vic and Dieuze, Western Germany; Bex, Switzerland; Northwich, England; also various places in Spain, India, China, Peru, Algeria, etc.

In the United States, New York, Michigan, Ohio, Kansas, Louisiana, California, West Virginia, Texas, and Utah possess large deposits and produce enormous quantities annually. In 1907 the production of the United States was 29,704,128 barrels of 280 pounds each, valued at \$7,439,551. The five districts producing the largest quantities were:

Michigan	10,786,630 barrels
New York	9,642,178 barrels
Ohio	3,851,243 barrels
Kansas	2,667,459 barrels
Louisiana	1,157,621 barrels

These districts produced about 95% of the output for 1907. The world's production is obtained principally, in the order named, from the United States, United Kingdom, Germany, Hungary, France, Spain, and Italy.

There are many explanations for the formation of salt deposits of such great thickness as indicated above. Of these the *bar theory* of Ochsenius is perhaps the most satisfactory. Ochsenius assumes that a portion of the ocean has been shut off from the main body of water by means of a bar, which rises almost to the surface. Evaporation within the bay would, on account of the shallowness of the water, be greatest on or near the bar. This would cause the water to become more dense and a portion would settle to the bottom behind the bar. In time the saturation of the water in the bay would be such as to cause the deposition of gypsum and rock salt. As the evaporation and concentration of the water continued, more would flow into the bay from the open ocean so that the supply would remain constant. If the bar emerges and entirely cuts off the bay continued evaporation would cause the deposition of not only calcium sulphate and rock salt, but also of the very soluble magnesium and potassium compounds. Owing to the very concentrated nature of the brine in the final stages of deposition many complex double salts result. The deposits at Stassfurt, Germany, cover an area of about 100 square miles and are an excellent illustration of the order in which the various compounds are deposited. In

these deposits four beds or "regions" are easily distinguished. Beginning with the lowest, they are:

(a) *Anhydrite region*. This bed is about 330 meters thick and in the upper portion consists of 96% rock salt and 4% anhydrite (CaSO_4), in the lower portions as much as 9% of anhydrite may be present. This region is underlain by gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and clay.

(b) *Polyhalite region*. This section is composed of 91.2% rock salt, 6.2% polyhalite ($2\text{CaSO}_4 \cdot \text{MgSO}_4 \cdot \text{K}_2\text{SO}_4 \cdot 2\text{H}_2\text{O}$), 1.5% tachydrite ($\text{CaCl}_2 \cdot 2\text{MgCl}_2 \cdot 12\text{H}_2\text{O}$), and 0.7% anhydrite. It has a thickness of about 62 meters.

(c) *Kieserite region*. This is about 56 meters thick and consists of 65% rock salt, 17% kieserite ($\text{MgSO}_4 \cdot \text{H}_2\text{O}$), 13% carnallite ($\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$), 3% tachydrite, and 2% anhydrite.

(d) *Carnallite region*. This zone consists of 55% carnallite, 25% rock salt, 16% kieserite, and 4% tachydrite. It is about 42 meters thick. Aside from the above, many other minerals, mostly salts of magnesium, calcium, and potassium, are found in this region.

(e) *Kainite region*. At Leopoldshall a deposit of considerable thickness of kainite ($\text{MgSO}_4 \cdot \text{KCl} \cdot 3\text{H}_2\text{O}$) is found above the carnallite region. It is thought that the kainite has resulted from the action of limited amounts of water on kieserite and carnallite.

The whole deposit is overlain by layers of saliferous clay, anhydrite, gypsum, and rock salt. Over thirty different minerals have been observed in the Stassfurt deposits of which halite, anhydrite, polyhalite, kieserite, carnallite, and a portion of the sylvite (KCl), bischofite ($\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$), and boracite ($2\text{Mg}_3\text{B}_8\text{O}_{15} \cdot \text{MgCl}_2$) are considered primary minerals.

(2) As an *efflorescence*, halite is found in the steppes, near the Caspian sea; in Africa and Chile.

(3) Near volcanoes it is found in small quantities as a *sublimation product*.

(4) Common salt also occurs abundantly *in solution* in the ocean, salt lakes, salt wells, etc., see page 67.

Salt is used extensively for household and dairying purposes, meat- and fish-packing, in the manufacture of sodium and its compounds, to glaze pottery, and in various metallurgical processes. Sodium carbonate is used in large quantities in glass and soap making, the bicarbonate for cooking and baking, also in medicine.

Cerargyrite, Horn Silver, AgCl .

Cubic, hexoctahedral class. Crystals are rare and poorly developed. The cube, octahedron, and rhombic dodecahedron are common forms

Twins according to the Spinel law. Usually massive and disseminated, as a crust or coating, stalactitic, dendritic.

No cleavage. Conchoidal fracture. Highly sectile, waxy. Very soft, hardness 1 to 1.5. Specific gravity 5.5 to 5.6. Pearly gray, yellowish, greenish, or white in color; on exposure to light turns violet, brown, or black. Resinous adamantine luster. Transparent to translucent. When rubbed becomes shiny. Streak shiny white.

AgCl, may contain mercury, ferric oxide, or other impurities. Fuses easily and yields a globule of silver. Not acted upon by acids. Slowly soluble in ammonium hydroxide.

Found as an alteration product in the upper levels of silver deposits. The usual associates are the various silver minerals, limonite, calcite, barite, etc. Occurs in considerable quantities at Johanngeorgenstadt and Freiberg, Saxony; Kongsberg, Norway; Peru; Chile; Mexico; Broken Hill, New South Wales; near Leadville, Colo.; Comstock Lode, Nev.; Poor Man's Lode, Idaho; various places in Utah; Cobalt district, Ontario.

Important ore of silver.

EMBOLITE, Ag(Cl,Br).

Cubic, hexoctahedral class. Crystals resemble those of cerargyrite. Usually massive. Sectile. Hardness 1 to 1.5. Specific gravity 5.31 to 5.81. Yellow, grayish green, or yellowish green in color. The percentages of chlorine and bromine vary considerably. Considered an isomorphous mixture in varying proportions of cerargyrite and bromyrite. Occurs rather abundantly in Chile, Mexico, and Australia.

BROMYRITE, Bromargyrite, AgBr.

Cubic, hexoctahedral class. Crystals and aggregates are similar to those of cerargyrite. Usually in small concretions. Malleable. Hardness 1 to 2. Specific gravity 5.8 to 6. Olive to yellow green in color. Often resembles amber in luster and color. Luster greasy and shiny. Siskin-green streak.

AgBr, generally contains some chlorine. Occurs in association with other silver minerals in the Plateros district of Mexico, and at Chañarcillo, Chile.

IODOBROMITE, Ag(Cl, Br, I).

Cubic, hexoctahedral class. Small crystals, usually the octahedron in combination with the cube. Soft. Specific gravity 5.7. Sulphur yellow to olive green in color. Resinous luster. Considered an isomorphous mixture of the chloride, bromide, and iodide of silver. Occurs in cavities of a ferruginous quartz near Dernbach, Nassau, Germany.

MIERSITE, AgI, usually contains some copper. Pale to bright yellow in color. Rhombic dodecahedral cleavage. Occurs at Broken Hill, New South Wales.

IODYRITE, Iodargyrite, AgI.

Hexagonal, dihexagonal pyramidal class. $a : c = 1 : 0.8204$. Pronounced hemimorphic development. Basal pinacoid usually predominates. Generally in thin plates, also compact and disseminated. Distinct basal cleavage. Hardness 1 to 1.5. Specific gravity 5.7. Pearly gray, yellow, lemon yellow, or green in color. Greasy luster. Shiny streak. Occurs with silver minerals near Dernbach, Nassau; Mazapil, Mexico; Chile; Spain; Lake Valley, Sierra Co., N. M.; Tonopah, Nevada, and Broken Hill, New South Wales.

FLUORITE GROUP

Here are placed the halogen compounds of bivalent metals which conform to the general formula $M'R'_2$. There are two series, one of which crystallizes in the cubic system, the other in the tetragonal.

CUBIC SERIES

HYDROPHILITE, CaCl_2 .

Hexoctahedral Class

FLUORITE, CaF_2 .

Hexoctahedral Class

TETRAGONAL SERIES

SELLAITE, MgF_2 .

Ditetragonal Bipyramidal Class

$$\frac{a}{c} : \frac{b}{c} = 1 : 0.6596$$
SCACCHITE, MnCl_2 .

?

?

LAWRENCITE, $(\text{Fe.Ni})\text{Cl}_2$.

?

?

Scacchite and lawrencite are very rare minerals.

HYDROPHILITE, Chlorocalcite, CaCl_2 . Occurs as crusts or cubic crystals, often coated with hematite, on Mt. Vesuvius.

FLUORITE, Fluor Spar, CaF_2 .

Cubic, hexoctahedral class. Excellent crystals are common. The usual form is the cube, either alone or in combination with the octahedron, rhombic dodecahedron, tetragonal trisoctahedrons ($m=2$ or 3), tetrahex-

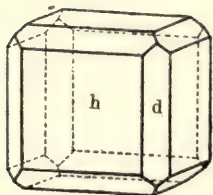


FIG. 53.

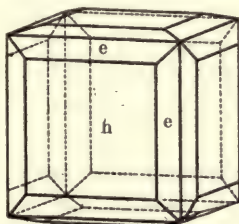


FIG. 54.

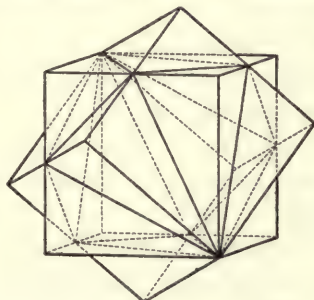


FIG. 55.

ahedrons ($m=2$ or 3), and hexoctahedron ($n=2$, $m=4$). The habit is generally cubic, although octahedral or rhombic dodecahedral crystals are sometimes observed. Figures 53 and 54 show some common combinations. The cube faces are usually smooth and brilliant, those of the octahedron rough and dull. Octahedral crystals are sometimes built up by parallel grouping of small cubes. Penetration twins, with the twinning plane parallel to a face of the octahedron, are rather common, Figure 55. Also

massive, granular, fine or coarse grained; rarely earthy, columnar, or compact.

Excellent octahedral cleavage. Brittle. Hardness 4. Specific gravity 3.1 to 3.2. Usually yellowish, greenish, or blue in color; also various shades of red, brown, white, and colorless. Some of the colors are supposed to be due to hydrocarbons, for many varieties become colorless when heated. Crystals are often multicolored. Transparent to subtranslucent. Vitreous luster. $n_{\text{Na}} = 1.4339$. Phosphoresces when heated. A bluish fluorescence is to be noted on many blue crystals from Cumberland, England.

CaF_2 . Usually very pure, sometimes contains small amounts of calcium chloride, calcium phosphate, etc. Heated in a closed tube, it decrepitates and phosphoresces. Fuses to a white enamel and colors flame red. Treated with sulphuric acid yields hydrofluoric acid.

Fluorite occurs in veins in gneiss, schists, limestones, and sandstones. It is also a common gangue mineral and is, hence, found with ores of lead, silver, copper, and especially tin. It is one of the characteristic associates of the "tin ore" deposits, see page 81. Calcite, quartz, barite, pyrite, galena, marcascite, chalcOPYrite, and sphalerite are some of the very common associates of fluorite. Excellent crystals occur at Cornwall, Cumberland, Derbyshire, etc., England; also found in the Freiberg district, Saxony; Harz Mts.; Kongsberg, Norway; St. Gotthard, Switzerland; etc.

In the United States fluorite occurs in considerable quantities in Hardin and Pope counties, Illinois; Smith, Trousdale, and Wilson counties, Tennessee; Crittenden, Livingston, Lyon, Caldwell, and Trigg counties, Kentucky; at Jamestown, Boulder Co., Colorado; various places in New York, Virginia, California, etc.

In 1907 the production of the United States was 49,486 tons. This was obtained from Illinois, Kentucky, Colorado and Tennessee in the order named.

Fluorite is used in the manufacture of open-hearth steel, cast iron, opalescent glass, hydrofluoric acid, enamels, glazes, and "agate" ware.

Fluorite is worth about \$9 per ton, when ground \$10 to \$14.

SELLAITE, MgF_2 . Tetragonal. Crystals are prismatic. Colorless. Vitreous luster. Translucent. Hardness 5. Specific gravity 2.97 to 3.15. Occurs in anhydrite at Gerbulaz, near Moutiers, Savoy, France.

TYSONITE GROUP

This includes minerals with the general formula $M'''R'_3$, where R' is an element of the halogen series.

MOLYSITE, $FeCl_3$.	Hexagonal System	$a : c$ 1 : 1.2350
TYSONITE, $(Ce.La.Di)F_3$.	Hexagonal System	1 : 1.3736

The class of symmetry in which these minerals crystallize has not yet been determined.

MOLYSITE, $FeCl_3$. Usually as yellowish, brownish, or brownish red crusts on the lavas of Mt. Vesuvius.

TYSONITE, $(Ce.La.Di)F_3$. Hexagonal. Generally in prismatic or thick tabular crystals. Excellent basal cleavage. Hardness 4.5 to 5. Specific gravity 6.13. Light waxy yellow to reddish brown in color. Vitreous to resinous luster, on cleavage surface somewhat pearly. Aside from the rare earths indicated in the formula, yttrium and erbium may be present. Occurs in granite in the Pike's Peak district, Colorado.

CALOMEL GROUP

Here are placed minerals possessing the formula $M'_2R'_2$, where M' may be copper, mercury, or lead, and R' any element of the halogen group.

NANTOKITE, Cu_2Cl_2 .	Cubic, Hextetrahedral Class
MARSHITE, Cu_2I_2 .	Cubic, Hextetrahedral Class
Calomel , Hg_2Cl_2 .	Tetragonal, Ditetragonal Bipyramidal Class
COTUNNITE, $PbCl_2$.	Orthorhombic, Bipyramidal Class

NANTOKITE, Cu_2Cl_2 . Cubic, artificial crystals belong to the hextetrahedral class. In nature only massive and granular. Hardness 2 to 2.5. Specific gravity 3.93. Colorless to white. Adamantine luster. Transparent to translucent. Occurs with hematite, cuprite, native copper, and other copper minerals at Nantoko, Chile; also at Broken Hill, New South Wales.

MARSHITE, Cu_2I_2 . Cubic, small tetrahedral crystals of an oily brown color. Translucent. Occurs in cerussite or anglesite at Broken Hill, New South Wales.

Calomel, Horn Mercury, Hg_2Cl_2 .

Tetragonal, ditetragonal class. $a : c = 1 : 1.7229$ In small, tabular, or pyramidal crystals. Contact and penetration twins. Crystals are often very complex.

Basal and pyramidal cleavages. Hardness 1 to 2. Specific gravity 6.4 to 6.5. Grayish and yellowish white in color, also yellow gray. Adamantine luster. Translucent to subtranslucent.

Hg_2Cl_2 . Volatilizes, without fusion, in a closed tube; also on charcoal, yielding white coating. Insoluble in water, soluble in aqua regia. Turns black when treated with alkalis.

Occurs with cinnabar at Moschellandsberg, Bavaria; Almaden, Spain; Idria, Carniola; Horowitz, Bohemia; El Doctor, Mexico.

COTUNNITE, PbCl_2 . Orthorhombic. Small white, acicular crystals. Prism angle is about 62° . Also in irregular grains. Adamantine luster. Prismatic cleavage. Hardness 2. Specific gravity 5.23. Easily fusible. Occurs as a sublimation product in the lavas of Mt. Vesuvius.

BISCHOFITE, $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$. Probably monoclinic. Natural crystals are rare. Usually granular, foliated, or fibrous. White. Very deliquescent. Occurs in the carnallite region, see page 101, of the salt deposits at Stassfurt, Germany. Formed by the solution of carnallite.

FLUELLITE, $\text{AlF}_3 \cdot \text{H}_2\text{O}$. Orthorhombic, $a : b : c = 0.770 : 1 : 1.874$. Small, steep pyramidal crystals. White. Hardness 3. Specific gravity 2.17. Transparent to translucent. Found with cassiterite at Cornwall, England. Very rare.

2. DOUBLE CHLORIDES AND FLUORIDES

CARNALLITE GROUP

Here belong double chlorides, with varying amounts of water of crystallization, of magnesium, calcium, iron, and potassium.

Carnallite, $\text{MgCl}_2 \cdot \text{KCl} \cdot 6\text{H}_2\text{O}$. Orthorhombic, Bipyramidal Class

DOUGLASITE, $\text{FeCl}_2 \cdot 2\text{KCl} \cdot 2\text{H}_2\text{O}$. ?

TACHYDRITE, $2\text{MgCl}_2 \cdot \text{CaCl}_2 \cdot 12\text{H}_2\text{O}$.

Hexagonal, Ditrigonal Scalenohedral Class

ERYTHROSIDERITE, $\text{FeCl}_3 \cdot 2\text{KCl} \cdot \text{H}_2\text{O}$. ?

KREMERSITE, $\text{FeCl}_3 \cdot 2(\text{K} \cdot \text{NH}_4)\text{Cl} \cdot \text{H}_2\text{O}$. ?

Erythrosiderite and kremersite are very rare minerals. They have been found on Mt. Vesuvius.

Carnallite, $\text{MgCl}_2 \cdot \text{KCl} \cdot 6\text{H}_2\text{O}$.

Orthorhombic, bipyramidal class. $a : b : c = 0.5968 : 1 : 1.3891$. Crystals possess hexagonal outline; rare. Usually massive and granular.

Conchoidal fracture. Hardness 1 to 2. Specific gravity 1.6. May be colorless, usually grayish, yellow, and due to admixtures of hematite or

goethite, often red. Vitreous luster. Deliquescent. Transparent to translucent. Bitter taste.

$\text{MgCl}_2 \cdot \text{KCl} \cdot 6\text{H}_2\text{O}$. May contain some sodium. Easily fusible. When dissolved in water it yields the chlorides of magnesium and potassium.

Occurs associated with rock salt and anhydrite in the salt deposits at Stassfurt, Germany, see page 100.

It is used in large quantities as a fertilizer, also as a source of potassium compounds. Mined extensively at Stassfurt, Germany.

DOUGLASITE, $\text{FeCl}_2 \cdot 2\text{KCl} \cdot 2\text{H}_2\text{O}$. Occurs in limited quantities in the salt deposits at Stassfurt, Germany.

TACHYDRITE, Tachyhydrite, $2\text{MgCl}_2 \cdot \text{CaCl}_2 \cdot 12\text{H}_2\text{O}$.

Hexagonal, ditrigonal scalenohedral class, $a : c = 1 : 1.90$. Wax to honey yellow masses. Rhombohedral cleavage. Deliquesces rapidly. A secondary mineral in the salt deposits at Stassfurt, Germany.

CRYOLITE, Eisstein, $\text{AlF}_3 \cdot 3\text{NaF}$.

Monoclinic, prismatic class. $a : b : c = 0.9662 : 1 : 1.3882$, $\beta = 90^\circ 11'$. Crystals are cubic in habit; were formerly considered orthorhombic and triclinic. Common forms are the unit prism, basal pinacoid, clinoid and orthodomes. Prism angle is $88^\circ 2'$. Contact and polysynthetic twins, twinning plane is parallel to a face of the unit prism. Usually in cleavable masses.

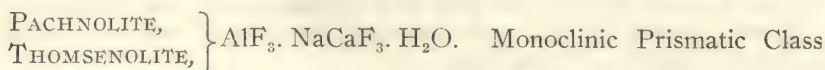
Basal and prismatic cleavages, three directions almost at right angles. Uneven fracture. Brittle. Hardness 2.5 to 3. Specific gravity 2.95 to 3.0. Colorless to snow white; more rarely reddish, brownish, or black. Pearly luster on the basal pinacoid, elsewhere vitreous to greasy. Transparent to translucent.

$\text{AlF}_3 \cdot 3\text{NaF}$. Usually quite pure. Sometimes contains a small amount of ferric oxide as an impurity. Fuses easily. Imparts a yellow color to the flame. Heated in open tube, it yields hydrofluoric acid which etches the tube.

Occurs in large quantities in veins in granite containing cassiterite at Ivigtut, Arksukfiord, Western Greenland, and is associated with siderite, quartz, chalcopyrite, pyrite, galena, sphalerite, fluorite, and columbite. This is the only important occurrence of cryolite. Is found in small quantities at Miask, Ural Mts., and in the Pike's Peak district, Colorado.

Cryolite is used in the manufacture of sodium salts, porcelain, milk glass, and as a bath in the manufacture of aluminium by the electrolytic process, especially at Niagara Falls, N. Y. Calcium fluoride is an important by-product in the manufacture of sodium salts from cryolite and substituted for fluorite (see page 104) as a flux in the open-hearth process of steel

manufacture. In 1907 about 1,438 long tons of cryolite, valued at \$28,902, were imported into the United States from Greenland.



These minerals possess the same chemical composition and crystallize with the same symmetry. Their elements of crystallization are also very similar, as is shown by the following comparison:

Pachnolite, $a : b : c = 1.1626 : 1 : 1.5320$, $\beta = 90^\circ 20'$.

Thomsenolite, $a : b : c = 0.9973 : 1 : 1.0333$, $\beta = 93^\circ 12'$.

They occur as prismatic crystals, or in coarse to fine crystalline, colorless crusts, resembling chalcedony. Alteration products of cryolite. Occur with cryolite in Western Greenland and Pike's Peak, Colorado.

3. OXYCHLORIDES AND OXYFLUORIDES

MATLOCKITE, Pb_2OCl_2 . Tetragonal. $a : c = 1 : 1.7627$. Small, thin tabular crystals. Uneven to conchoidal fracture. Hardness 2.5. Specific gravity 7.2. Adamantine to pearly luster. Yellowish or greenish in color. Transparent to translucent. Alteration product of galena. Occurs at Cromford, near Matlock, Derbyshire, England.

PERCYLITE, $\text{Pb}(\text{OH})\text{Cl} \cdot \text{Cu}(\text{OH})\text{Cl}$. Tetragonal, also considered cubic. Small azure-blue crystals. Vitreous luster. Occurs with gold at Sonora, Mexico; with galena in Chile. *Boleite* from Boléo, California, and Broken Hill, New South Wales, is an argentiferous percyelite.

Atacamite, $\text{Cu}(\text{OH})\text{Cl} \cdot \text{Cu}(\text{OH})_2$.

Orthorhombic, bipyramidal class. $a : b : c = 0.6613 : 1 : 0.7529$. Usually in slender prismatic crystals, consisting of the unit prism, unit brachydome, and brachypinacoid. Prisms are striated vertically. Also massive, reniform; radial, foliated, granular, and compact aggregates; sometimes as a sand or crust.

Perfect brachypinacoidal cleavage. Conchoidal fracture. Hardness 3 to 3.5. Specific gravity 3.76. Color various shades of green. Apple green streak. Vitreous luster. Subtransparent to translucent.

$\text{Cu}(\text{OH})\text{Cl} \cdot \text{Cu}(\text{OH})_2$. Yields water at 200°C . Fuses on charcoal, colors flame azure-blue, and yields a globule of copper. Easily soluble in acids and ammonium hydroxide.

Usually associated with various copper minerals. Occurs in considerable quantities in the provinces of Atacama and Tarapaca, Chile; Bolivia; Southern Australia; India; Arizona; as a sublimation product on Mt. Vesuvius.

In Chile atacamite is an important ore of copper.

V. NITRATES, CARBONATES, MANGAN- ITES, AND PLUMBITES

1. NITRATES

Here are placed the nitrates of sodium and potassium. Owing to their great solubility, these compounds do not occur in extensive deposits, except under the most favorable conditions.

SODA NITER, NaNO_3 . Hexagonal, Ditrigonal Scalenohedral Class $\begin{matrix} a & : & c \\ 1 & : & 0.8276 \end{matrix}$
(*Chile Saltpeter*)

Niter, KNO_3 . Orthorhombic Bipyramidal Class $\begin{matrix} a & : & b & : & c \\ 0.5843 & : & 1 & : & 0.7028 \end{matrix}$
(*Saltpeter*)

Chile saltpeter is of great importance, commercially.

SODA NITER, Chile Saltpeter, NaNO_3 .

Hexagonal, ditrigonal scalenohedral class, $a : c = 1 : 0.8276$. Rarely found in crystals. They resemble those of calcite. Generally in crystalline aggregates or grains, also in crusts or deposits of great extent.

Perfect rhombohedral cleavage. Conchoidal fracture. Brittle. Hardness 1.5 to 2. Specific gravity 2.1 to 2.3. Vitreous luster. Colorless, white, yellowish, or reddish brown. Transparent. Cooling and saline taste. Strong double refraction, $\omega_{\text{Na}} = 1.5874$, $\epsilon_{\text{Na}} = 1.3361$.

NaNO_3 , usually contains some sodium chloride and sulphate. Easily soluble in water, one part in three of water at 15°C . Deliquesces. Colors flame an intense yellow.

Occurs in large deposits, 6 to 12 feet thick, in the province of Tarapaca, Chile, and at Arane, Bolivia. It is mixed with rock salt, guano, and other minerals in small quantities, among them lautarite, $\text{Ca}(\text{IO}_3)_2$. The beds of Chile saltpeter alternate with layers of gypsum, sand and clay. The raw material is called *caliche*. These deposits are supposed to have resulted from the oxidation of nitrogenous organic matter, especially guano, in the presence of soda; perhaps nitrifying bacteria assist in this reaction. In smaller quantities soda niter occurs in San Bernadino and Inyo counties, California; also in Nevada and New Mexico.

Soda niter is of great value, commercially. It is used extensively as

a fertilizer, in the manufacture of nitric acid and potassium nitrate. Owing to its tendency to deliquesce it cannot be used in gunpowder except in very dry places, for example, in salt mines. Hence, it is converted into the non-hygroscopic potassium nitrate by treating it with a solution of potassium chloride, which occurs in large quantities as sylvite, page 98, or is easily obtained from carnallite, page 106. Chile saltpeter is also the chief source of the iodine of commerce. In 1906 Chile exported 1,719,000 long tons of soda niter, 372,222 tons coming to the United States. The remainder was sent to Europe, principally to Germany. It is thought that at the present rate of consumption the Chilean deposits will last about fifty years.

Niter, Saltpeter, KNO_3 .

Orthorhombic, bipyramidal class. $a : b : c = 0.5843 : 1 : 0.7028$. Artificial crystals are pseudo-hexagonal, the prism angle being $118^\circ 50'$. In nature only as crusts, fine, slender, acicular crystal aggregates; also as a powdery efflorescence.

Crystals possess indistinct prismatic and brachypinacoidal cleavages. Conchoidal fracture. Brittle. Hardness 2. Specific gravity 1.9 to 2.1. Vitreous luster. Colorless, white, or gray.

KNO_3 . Easily soluble in water. Non-hygroscopic. Colors flame violet.

Occurs as an efflorescence in dry regions, thus in northern Africa, Hungary, India, and in many of the western states; also in limestone caves at Leonhardshöhle, near Homburg, Germany; Calabria; Ceylon; Brazil; Kentucky; Missouri; and in small quantities in the deposits of Chile saltpeter in Chile. It is usually the result of the oxidation of nitrogenous matter in the presence of potash. It is thought that nitrifying bacteria aid in this change.

The mineral is not used to any extent. The artificial compound, obtained principally by the interaction of sodium nitrate and potassium chloride, pages 98 and 109, is used in large quantities in gunpowder, fireworks, matches, as a flux, and as a mordant in dyeing and printing.

2. CARBONATES

A. NORMAL AND ACID CARBONATES

CALCITE-ARAGONITE GROUPS

These groups form an isodimorphous series and embrace those minerals which possess the general formula $\text{M}''\text{CO}_3$. The metal may be calcium, magnesium, zinc, iron, manganese, barium, strontium, or lead. The members of the calcite group crystallize in the ditrigonal scalenohedral class of the hexagonal system, those of the aragonite group in the orthorhombic bipyramidal class. Dolomite, $\text{CaMg}(\text{CO}_3)_2$, possesses a lower grade of

symmetry than the members of the calcite group but on account of the similarity of chemical composition and physical properties it is added to the group.

CALCITE GROUP

(HEXAGONAL SYSTEM)

		$a :$	c
CALCITE, CaCO_3.	Ditrigonal Scalenohedral Class	I :	0.8543
DOLOMITE, $\text{CaMg}(\text{CO}_3)_2$.	Trigonal Rhombohedral Class	I :	0.8322
ANKERITE, $(\text{Ca}, \text{Mg}, \text{Fe})\text{CO}_3$.	Ditrigonal Scalenohedral Class	I :	0.8100
		I :	0.8300
MAGNESITE, MgCO_3.	Ditrigonal Scalenohedral Class	I :	0.8104
BREUNNERITE, $(\text{Mg}, \text{Fe})\text{CO}_3$.	Ditrigonal Scalenohedral Class	I :	0.8129
SMITHSONITE, ZnCO_3.	Ditrigonal Scalenohedral Class	I :	0.8062
MONHEIMITE, $(\text{Zn}, \text{Fe})\text{CO}_3$.	Ditrigonal Scalenohedral Class	I :	0.8170
RHODOCHROSITE, MnCO_3.	Ditrigonal Scalenohedral Class	I :	0.8183
MANGANOCALCITE, $(\text{Mn}, \text{Ca})\text{CO}_3$.			to
MANGANOSIDERITE, $(\text{Mn}, \text{Fe})\text{CO}_3$.		I :	0.8218
OLIGONITE, $(\text{Fe}, \text{Mn})\text{CO}_3$.		I :	0.8175
SIDERITE, FeCO_3.	Ditrigonal Scalenohedral Class	I :	0.8184
SPHAEROCOBAULTITE, CoCO_3.	Ditrigonal Scalenohedral Class		?

ARAGONITE GROUP

(ORTHORHOMBIC SYSTEM)

		a	b	c
ARAGONITE, CaCO_3.	Bipyramidal Class	0.6228	I :	0.7204
STRONTIANITE, SrCO_3.	Bipyramidal Class	0.6089	I :	0.7237
BROMLITE, $(\text{Ca}, \text{Ba})\text{CO}_3$.	Bipyramidal Class	0.5871	I :	0.7390
WITHERITE, BaCO_3.	Bipyramidal Class	0.5949	I :	0.7413
TARNOWITZITE, $(\text{Ca}, \text{Pb})\text{CO}_3$.	Bipyramidal Class	0.6220	I :	0.7168
CERUSSITE, PbCO_3.	Bipyramidal Class	0.6101	I :	0.7229

The members of the calcite group possess, when crystallized, a perfect rhombohedral cleavage, the angle varying from 105° to 107° . The prism angle of the aragonite group of minerals is approximately 120° , varying between $116^\circ 12'$ and $117^\circ 48'$.

CALCITE, Calcspar, Iceland Spar, etc., CaCO_3 .

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 0.8543$. Commonly in well developed crystals, often very complex, Figure 59. The habit varies greatly, may be obtuse or acute rhombohedral, thin tabular, long prismatic, or scalenohedral. Over 200 forms have been observed. The

unit rhombohedron occurs rarely as an independent form. No less than 750 different combinations have been noted. Figures 56 to 59 show several common types of development and combinations.

Twins are relatively common. Four laws may be referred to. (1) Basal pinacoid acts as the twinning plane. Such twins are rather common, Figure 60. (2) The rhombohedron, $-\frac{1}{2}R$, is the twinning plane. Con-

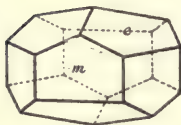


FIG. 56.

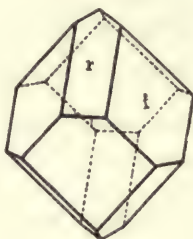


FIG. 57.

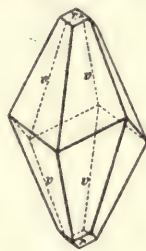


FIG. 58

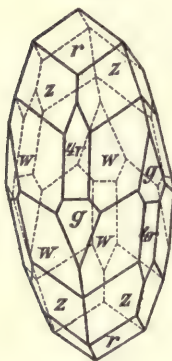


FIG. 59.

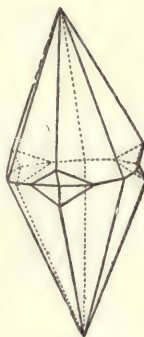


FIG. 60.

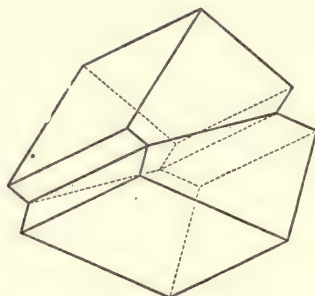


FIG. 61.

tact and polysynthetic twins according to this law are exceedingly common. Figure 61 shows a contact twin with $-\frac{1}{2}R$ as the twinning plane. (3) The unit rhombohedron is the twinning plane. The vertical axes are inclined at angles of $90^{\circ}46'$ and $89^{\circ}14'$. This is not a common law. (4) The rhombohedron, $2R$, acts as twinning plane. The vertical axes intersect at angles of $53^{\circ}46'$ and $126^{\circ}14'$. Crystals twinned according to this law are sometimes heart-shaped.

Also in granular, lamellar, fibrous, compact, or earthy masses; oolitic or pisolitic, stalactitic, nodular, etc.

Highly perfect rhombohedral cleavage ($105^{\circ}5'$). Conchoidal fracture, very rarely observed. Hardness 3. Specific gravity 2.6 to 2.8, when pure 2.72. Vitreous to subvitreous luster, also earthy. Colorless, white, gray, yellow, various shades of red, green, blue, etc. Streak white. Transparent to opaque. Strong double refraction, $\omega_{Na} = 1.6585$, $\epsilon_{Na} = 1.4863$.



CaCO_3 . Sometimes very pure. May contain varying amounts of magnesium, iron, manganese, zinc, lead, cobalt, barium, or strontium replacing the calcium. Often mixed with limonite, hematite, organic matter, sand, or brucite. Infusible before the blowpipe, glows, and becomes alkaline. Imparts a red color to the flame. Easily soluble with brisk effervescence in cold dilute acids. *Meigen's test* is useful to distinguish compact calcite from aragonite:—calcite powder, when boiled for several minutes with cobalt solution either remains white or turns a pale yellow, aragonite, however, assumes a lilac-red color. Occurs as a pseudomorph after aragonite, barite, fluorite, anhydrite, and gypsum. Calcite alters to gypsum and dolomite. Is sometimes replaced by quartz or chalcedony. Pseudomorphs of siderite, smithsonite, cerussite, and malachite after calcite are not uncommon.

The different varieties of calcite may be grouped as follows: (a) *Ordinary*, (b) *Limestones*, (c) *Marbles*, (d) *Chalk and Marl*, and (e) *Spring, Stream, and Cave Deposits*.

(a) **Ordinary calcite.** Here are placed the crystallized, fibrous, and lamellar varieties.

(1) *Dog-tooth spar.* Scalenohedral crystals.

(2) *Nail-head spar.* Crystals resembling the head of a nail.

(3) *Iceland spar.* Colorless and transparent varieties, especially from Eskifjord, Iceland.

(4) *Fontainebleau limestone.* Crystals of calcite from Fontainebleau and Nemours, France, and elsewhere, containing as much as 50 to 63% of sand.

(5) *Satin spar.* Fibrous variety, with silky luster. White, grayish, or yellow in color.

(6) *Argentine.* Lamellar calcite with a pearly luster.

(7) *Anthraconite, stinkstone.* A bituminous calcite. When struck, yields a fetid odor.

(b) **Limestones.** This includes many massive varieties, which (1) may be dull and compact, (2) coarse or fine granular, and (3) composed of fragmental material.

(1) *Compact limestones.* These may be nearly white, yellow, bluish gray, reddish or black in color.

(2) *Magnesian or dolomitic limestones.* These are limestones containing varying percentages of magnesium carbonate.

(3) *Lithographic limestone.* An even-grained, compact limestone, suitable for lithographic purposes. That from Solenhofen, Bavaria, is buff or drab in color.

(4) *Hydraulic limestone.* An impure limestone, containing varying amounts of magnesia, silica, and alumina. After ignition will set under water.

(5) *Bituminous limestone*. Contains considerable organic matter. When struck yields characteristic odor of bitumen.

(6) *Granular limestone*. Compact, but consists of glistening grains of calcite, see Figure 62. Metamorphosed limestone. Sometimes termed crystalline limestone.

(7) *Coquina*. Consists of shell remains.

(8) *Oolitic limestone*. This consists of small, spherical concretions, resembling fish-roe.

(9) *Pisolithic limestone*. The concretions are the size of a small pea.

(c) **Marbles**. Limestones, capable of taking a polish and suitable for ornamental and structural purposes, are termed marble. They are usually crystalline, Figure 62 (after Weinschenk), and fine to coarse granular.

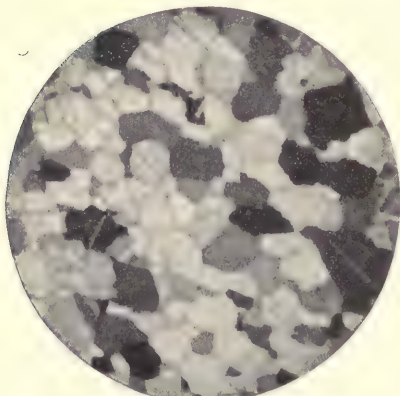


FIG. 62.

(d) **Chalk and marl**. Very soft, earthy varieties.

(1) *Chalk*. Soft, white, earthy masses, consisting of organic remains, especially foraminifera, inoceramus, pecten, ostrea, etc.

(2) *Marl*. Soft, earthy calcareous deposit, mixed with clay. May contain shell or other organic remains.

(e) **Spring, stream, and cave deposits**. These are largely due to the

escape of carbon dioxide, which causes the very soluble calcium bicarbonate, $\text{CaH}_2(\text{CO}_3)_2$, to pass over to the more insoluble normal carbonate, CaCO_3 , and be deposited. It is thought that certain algae aid in this process.

(1) *Travertine, calcareous sinter, calc tufa, etc.* Deposits formed around springs and in stream beds. They are usually porous and often contain twigs, leaves, and other organic remains. Sometimes they are compact and banded, and then termed *onyx*, *onyx marble*, or *Mexican onyx*.

(2) *Stalactites*. Icicle-like forms suspended from the roofs of caves.

(3) *Stalagmites*. Deposits on the floors of caves, usually conical in form.

(4) *Stagmites*. Cave deposits, either stalactites or stalagmites. The term *onyx marble* is also applied to these deposits.

(5) *Thinolite*. Here may be added a tufa-like deposit of a gray or brownish color, occurring in large quantities in many lakes of Nevada and California.

Calcite occurs very widely distributed. It is a common associate of metalliferous ore deposits; as limestone, marble, chalk, and marl it occurs

in large deposits, often of great thickness and extending over wide areas; common in cracks and cavities in igneous and sedimentary rocks; and abundant as spring, stream, and cave deposits. Excellent crystals are very common. A few of the noted localities are: Eskifjord, Iceland; Matlock and Eyam, Derbyshire; Egremont and Alston, Cumberland; Weardale, Durham; Furness, Lancashire; Andreasberg, Hartz Mountains; Kapnik, Hungary; Joplin, Missouri; Rossie, St. Lawrence Co., New York, and the Lake Superior Copper district. In the United States large deposits of marble occur in Vermont, New York, Georgia, Tennessee, Massachusetts, Maryland, Pennsylvania, and California.

The different varieties of calcite are of great value, commercially. Iceland spar is used in optical instruments; limestone for building purposes, quicklime, cement, flux in various metallurgical processes, railroad ballast, macadam, in lithography, concrete, etc.; marble for building, ornamental, monumental and statuary purposes, and as a source of carbon dioxide; chalk for whiting, crayon, scouring and polishing preparations, also as an adulterant; marl for cement.

DOLOMITE, Pearl Spar, $\text{CaMg}(\text{CO}_3)_2$.

Hexagonal, trigonal rhombohedral class. $a : c = 1 : 0.8322$. Rhombohedral crystals are common. The faces are often curved, forming saddle-shaped crystals. The unit rhombohedron is very common; also more acute modified rhombohedrons of the first order, especially those with the coefficient $m = 2$ or 4; now and then rhombohedrons of the second order, the characterizing forms of the trigonal rhombohedral class, are observed. The symmetry of this class is also revealed by the etch figures. Figure 63 shows a combination of the basal pinacoid c , unit and modified rhombohedrons of the first order r and m , and the rhombohedron of the second order n with the coefficient m equal to $16/3$. Some crystals are rather complex. Twins, with the twinning plane parallel to the basal pinacoid, are not uncommon. The modified rhombohedron of the first order, $-2R$, also acts as a twinning plane. This is not a common law. Commonly in coarse to fine grained masses.

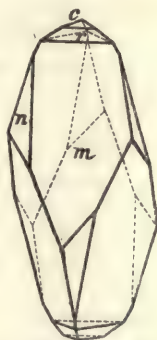


FIG. 63.

Perfect rhombohedral cleavage. Conchoidal to sub-conchoidal fracture. Brittle. Hardness 3.5 to 4. Specific gravity 2.80 to 2.95. Vitreous to pearly luster. White, reddish, yellow, brown, or black. Transparent to translucent.

$\text{CaMg}(\text{CO}_3)_2$. Sometimes with small amounts of iron and manganese. According to Bauer the composition of almost all crystals is CaCO_3 :

$\text{MgCO}_3 = 1 : 1$, *normal dolomite*. However, the ratio of the two carbonates varies greatly, usually CaCO_3 predominates. Infusible before the blowpipe, becomes alkaline. Fragments are but slightly acted upon by cold dilute acid. The powder effervesces briskly with hot dilute acid. Occurs as a pseudomorph after calcite, anhydrite, fluorite, barite, and cerussite.

Two general varieties of dolomite may be distinguished: (1) *crystallized* and (2) *crystalline*.

(1) *Crystallized dolomite* occurs abundantly in many ore deposits and in cavities of various igneous and sedimentary rocks. Some important localities are: Hall, Austria; St. Gotthard, Bex, and elsewhere, Switzerland; Kapnik, Hungary; Clausthal, Hartz Mountains; Freiberg, Saxony; Lockport and vicinity, N. Y.; Joplin, Mo.; Stony Point, N. C.; and Roxbury, Vt.

(2) *Crystalline dolomite*. This is a compact, granular variety and often occurs in enormous deposits of great thickness and extent. Many mountain ranges in central Europe are principally dolomite. Crystalline dolomite grades into dolomitic or magnesian limestone, see page 113. Crystalline dolomites are thought to have resulted in several ways, as follows: (1) As a deposit from lagoons or salt lakes, due to the action of concentrated magnesian brines upon organically formed aragonite. Such dolomites are generally associated with gypsum and rock salt. (2) By the action of solutions containing magnesian salts, such as MgCl_2 or MgSO_4 , upon limestones, especially coral reefs. (3) By the leaching of the more soluble calcium carbonate from magnesian limestones. This would tend to increase the percentage of magnesium carbonate. Certain organisms, among them lithothamnia, contain as much as 13% MgCO_3 , the remainder being essentially CaCO_3 .

Dolomite is used extensively for building, statuary, monumental, and ornamental purposes; as a source of magnesium compounds; and as a refractory material.

ANKERITE, $(\text{Ca}, \text{Mg}, \text{Fe})\text{CO}_3$.

Hexagonal, ditrigonal scalenohedral class. $a : c$ varies from 1 : 0.81 to 1 : 0.83. Rhombohedral crystals. Usually in compact or granular masses. Rhombohedral cleavage. Gray, white, reddish, or brown in color. Vitreous to pearly luster.

Ankerite is a ferruginous or manganiferous dolomite, containing about 50% of CaCO_3 , 25 to 30% MgCO_3 , 5 to 20% FeCO_3 , and at times 2 to 3% MnCO_3 . It is generally found in metalliferous veins. Siderite is a common associate.

MAGNESITE, MgCO_3 .

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 0.8104$. Not often in rhombohedral crystals. Usually in granular, compact, or earthy masses, resembling unglazed porcelain.

Crystals have a perfect rhombohedral cleavage. Conchoidal fracture.

Brittle. Hardness 3.5 to 4.5. Specific gravity 2.9 to 3.1. Transparent to translucent. Colorless, white, yellow, brown, or blackish.

MgCO_3 . May contain some iron, manganese, or calcium. Infusible, if ferruginous becomes magnetic. Powder is soluble in hot dilute acids.

Magnesite is commonly an alteration product of magnesium rocks, due to hydration and carbonization. Thus, olivine, $(\text{Mg,Fe})_2\text{SiO}_4$, may alter to serpentine, magnesite, limonite, and opal. Hence, it is usually found in veins in talcose and chloritic schists, serpentine, and other magnesian rocks. It occurs in Moravia and Styria, Austria; Silesia; Zillerthal, Tyrol; Snarum, Norway; Greece; Bolton and Roxbury, Mass.; Lancaster and Chester counties, Pa.; Tulare, Stanislaus, Santa Clara, Contra Costa, Napa, and Sonoma counties, California.

Magnesite is used extensively as a source of carbon dioxide and magnesium compounds. Calcined magnesite is used in refractory bricks for basic linings in converters, as an adulterant of paint, and in medicine. Most of the magnesite of commerce is obtained from Austria-Hungary, Germany, Greece, California, and India.

BREUNNERITE, $(\text{Mg,Fe})\text{CO}_3$.

This includes various varieties of ferruginous magnesite which are intermediate between magnesite and siderite, such as, *mesitite* and *pistomesite*. White, yellowish, brown, rarely black, in color. Sometimes turns black on exposure. Specific gravity 3 to 3.4. Found at Traversella, Piedmont; Salzburg, Austria.

SMITHSONITE, Calamine, Dry Bone, ZnCO_3 .

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 0.8062$. Crystals are small, usually rough and curved. They often occur in groups on the surface of compact crusts and stalactites. Generally reniform, botryoidal, or stalactitic; also in cellular crusts with a granular, fibrous, or compact structure. The cellular or porous varieties are sometimes called *dry bone*.

Perfect rhombohedral cleavage. Uneven to splintery fracture. Brittle. Hardness 5. Specific gravity 4.1 to 4.5. Vitreous to pearly luster. Translucent to opaque. Colorless, yellow, brown, gray, blue, green, or orange yellow. Streak white.

ZnCO_3 . Usually with some iron, manganese, cobalt, calcium, magnesium, and at times considerable cadmium. The smithsonite from Wiesloch, Germany, contains about 3% CdCO_3 . *Turkey fat* is a term often applied to yellow smithsonite containing greenockite, CdS . A variety from Boléo, California, contains 10.27% cobalt oxide. Is often mixed with sand, clay, ferric oxide, limestone, and dolomite. Infusible before the blowpipe. Gives zinc, and often cadmium, reactions. Easily soluble in hot acids. Common as a pseudomorph after calcite, especially at Mineral Point, Wis.

Usually associated with zinc minerals, especially sphalerite and hemimorphite, also galena and limonite. It is a secondary mineral and occurs extensively in the upper levels in limestones and dolomites. It is often the result of the action of carbonated waters on other zinc minerals. Occurs at Aachen, in Westphalia, Wiesloch in Baden, and elsewhere in Germany; Bleiberg and Raibl, Carinthia; Chessy, France; Hungary; Algeria; Matlock and Mendip Hills near Bristol, England.

In the United States it is found at Lancaster, Pa.; Mineral Point, Wis.; many places in Missouri, Arkansas, Iowa, and Virginia.

It is an important zinc ore. The term *calamine* is sometimes applied to smithsonite, but it refers more properly to hemimorphite, H_2ZnSiO_5 .

MONHEIMITE, $(\text{Zn}, \text{Fe})\text{CO}_3$, is a ferruginous smithsonite, and may contain as high as 50% FeCO_3 .

RHODOCHROSITE, MnCO_3 .

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 0.8183$. Crystals usually show the unit rhombohedron; sometimes rather small and drusy. Generally in compact or granular masses, also globular, reniform, botryoidal, and in crusts.

Perfect rhombohedral cleavage. Conchoidal to uneven fracture. Brittle. Hardness 3.5 to 4.5. Specific gravity 3.3 to 3.6. Rarely colorless, most generally rose red, also gray, yellow, brown, green; and due to alteration, black. Vitreous to pearly luster. Streak white. Translucent.

MnCO_3 . May contain as much as 25% CaCO_3 (*manganocalcite*), 40% FeCO_3 (*manganosiderite*), 4% MgCO_3 ; also small amounts of zinc and cobalt. Infusible before the blowpipe, turns greenish or black. Reacts for manganese. Easily soluble in warm dilute acids. Occurs as a pseudomorph after calcite and fluorite.

Commonly found with deposits of iron, lead, gold, silver, copper, and manganese minerals, thus at Freiberg, Saxony; Kapnik, Hungary; Nagyág, Transylvania; Hambach near Diez, Nassau; Mine Hill, Franklin Furnace, N. J.; Alicante, Lake Co., Colo.; Butte, Mont.; Austin, Nevada.

MANGANOCALCITE, $(\text{Mn}, \text{Ca})\text{CO}_3$, is a rhodochrosite containing as much as 25% calcium carbonate.

OLIGONITE, $(\text{Fe}, \text{Mn})\text{CO}_3$, is a manganiferous siderite.

SIDERITE, Spathic Iron, Chalybite, FeCO_3 .

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 0.8184$. Rhombohedral crystals are rather common, often distorted and with curved faces. Crystals usually show the unit rhombohedron alone, or in combination with the modified rhombohedrons $-\frac{1}{2}\text{R}$, -2R , and 4R , the prisms of the

first and second orders, various scalenohedrons, and the basal pinacoid. Commonly in coarse to fine granular masses, also botryoidal, globular, or concretionary.

Perfect rhombohedral cleavage. Conchoidal to splintery fracture. Brittle. Hardness 3.5 to 4.5. Specific gravity 3.7 to 3.9. Vitreous to pearly luster. Usually brownish to brownish red in color; also ashen gray, yellowish gray, greenish gray, green, and white. Fresh varieties have a white streak.

FeCO_3 . Usually contains some CaCO_3 and MnCO_3 . The manganese varieties are termed *oligonite*. Mixed with clay, sand, and organic matter, it is called *clay ironstone* or *blackband*. Infusible before the blow-pipe, turns black. Becomes magnetic. Reacts for iron. Effervesces with acids. Occurs as a pseudomorph after fluorite, aragonite, calcite, dolomite, barite, pyrite, and galena. It alters to limonite, hematite, and sometimes to magnetite.

Siderite occurs commonly with sulphide ore deposits, also in beds and concretions in limestones and shales. The common associates of siderite are pyrite, galena, chalcopryrite, cryolite, tetrahedrite, etc. It occurs with ore deposits in the Hartz Mts.; Pribram, Bohemia; Cornwall, England; Freiberg, Saxony, etc. With cryolite and chalcopryrite in western Greenland. In beds and as concretions in Westphalia; southern Wales; Silesia, etc. In the United States it is found in eastern Ohio, Kentucky, and western Pennsylvania, principally in beds in the Lower Coal measures.

It is sometimes used as an ore of iron. In 1906 the United States produced 17,996 tons of siderite. This was only a fraction of one percent of the iron ore mined that year.

SPHAEROCOBALTITE, CoCO_3 . Hexagonal, ditrigonal scalenohedral class. Rarely in crystals. Usually in coarse, radial, spherical masses. Velvet black on the surface, rose red in the interior. Reddish streak. Hardness 4. Specific gravity 4 to 4.13. Found at Schneeberg, Saxony.

ARAGONITE, Flos Ferri, CaCO_3 .

Orthorhombic, bipyramidal class. $a : b : c = 0.6228 : 1 : 0.7204$. Crystals are rather common and show great diversity in development. They may be domatic (chisel-like), acute pyramidal (spear-shaped), and prismatic (often pseudo-hexagonal). Many forms have been observed. Figure 64 shows a common combination which consists of m the unit prism, b brachypinacoid, and k unit brachydome. The prism angle is $116^\circ 12'$, hence, often hexagonal in outline. This pseudo-hexagonal symmetry is accentuated by twinning. Twins are more common than simple crystals. Usually the unit prism acts as the twinning plane. Contact (Figure 65),

polysynthetic (Figure 66), cyclic, and penetration (Figure 67) twins are commonly observed. Figure 68 shows clearly the pseudohexagonal symmetry of penetration trillings. Also in radial, columnar and fibrous aggregates, stalactitic, branching forms, crusts, reniform, and globular.

Brachypinacoidal and prismatic cleavages, rather imperfect. Conchoidal fracture. Brittle. Hardness 3.5 to 4. Specific gravity 2.9 to 3. Colorless, white, gray, yellow, reddish, green, bluish, and black. Streak

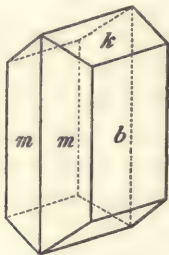


FIG. 64.

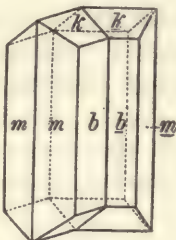


FIG. 65.

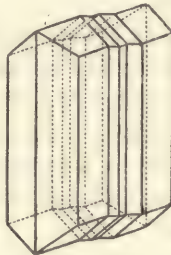


FIG. 66.

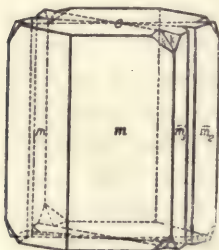


FIG. 67.

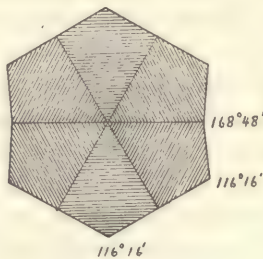


FIG. 68.

white. On fracture surfaces greasy luster, elsewhere vitreous. Transparent to translucent.

CaCO_3 . May contain strontium, iron, manganese, lead, or zinc. Effervesces easily in acids, but not as readily as calcite. *Meigen's test* is the best chemical reaction to differentiate definitely massive aragonite from calcite, see page 113. Aragonite occurs as a pseudomorph after gypsum and calcite. More abundant are, however, calcite pseudomorphs after aragonite. At about 600°C ., aragonite is changed to calcite.

Aragonite is usually deposited from aqueous solutions with a temperature over 30°C ., at a lower temperature calcite is formed. Aragonite is found (1) in cracks and cavities in various kinds of rocks and is usually associated with the zeolites. (2) In ore deposits, especially iron ore. The coralloidal variety occurring with siderite at Hüttenberg, Carinthia, is termed *flos ferri*. (3) Disseminated in clay. Here aragonite is generally

associated with gypsum, sulphur, and celestite. (4) As a deposit from hot springs and geysers, sometimes pisolitic and in crusts. (5) Aragonite constitutes the pearly layer of many shells and pearls. Aragonite is not nearly as common as calcite. Some noted localities are: Herregrund, Hungary; Bilin, Karlsbad, and Horschenz, Bohemia; Molina, Aragon, Spain; Girgenti, Sicily; Alston Moor, England; Hoboken, N. J.; Lockport, N. Y.; Warsaw, Ill.; Haddam, Conn., etc.

Aragonite is of no importance, commercially.

STRONTIANITE, SrCO_3 .

Orthorhombic, bipyramidal class. $a : b : c = 0.6089 : 1 : 0.7237$. Crystals are usually spear-shaped or acicular. They are often arranged in radial aggregates. Forms and twins similar to aragonite, page 119. Pseudo-hexagonal symmetry, prism angle is $117^\circ 19'$. Also granular and compact, sometimes with a radial, fibrous structure.

Imperfect prismatic cleavage. Conchoidal fracture. Brittle. Hardness 3.5 to 4. Specific gravity 3.6 to 3.8. Vitreous luster, greasy on fracture surfaces. Colorless, gray, yellow, yellowish brown, and green. Streak white. Transparent to translucent.

SrCO_3 . Usually contains some calcium and barium. *Emmonite*, or *calciostrontianite*, from Brixlegg, Tyrol, contains as much as 13% of CaCO_3 . Fuses on the edges, imparts a crimson color to the flame, and becomes alkaline. Easily soluble with effervescence in cold dilute acids. Occurs as a pseudomorph after celestite.

Occurs in ore deposits, commonly with barite and galena. Thus, at Clausthal, Hartz Mts.; Freiberg, Saxony; Hamm in Westphalia, Germany; Strontian in Argyllshire, Scotland; Schoharie and Clinton, also various places in Jefferson county, N. Y.; Ida, Monroe Co., Mich.; Mount Bonnell and Mount Baker, near Austin, Texas.

Strontianite is the chief source of strontium compounds, many of which are used extensively in the chemical laboratory. The oxide and hydroxide are of importance in the precipitation of sugar from molasses; the nitrate, carbonate, and oxalate are used for red fire; the iodide, bromide, and lactate in medicine. Most of the strontianite used in the United States is imported from Westphalia, where it occurs in veins in rocks of cretaceous age.

BROMLITE, Alstonite, $(\text{Ca}, \text{Ba})\text{CO}_3$.

Orthorhombic, bipyramidal class. $a : b : c = 0.5871 : 1 : 0.7390$. An isomorphous mixture of CaCO_3 and BaCO_3 . Crystals are usually acute pyramidal, pseudo-hexagonal. Hardness 4 to 4.5. Specific gravity 3.65 to 3.76. Colorless to grayish white. Luster is slightly greasy. Translucent. Occurs at Fallowfield, near Hexham, Northumberland; also at Bromley Hill, near Alston, Cumberland.

WITHERITE, BaCO_3 .

Orthorhombic, bipyramidal class. $a : b : c = 0.5949 : 1 : 0.7413$. Usually in pseudo-hexagonal bipyramids, resembling quartz. These are penetration trillings with the twinning plane parallel to the unit prism. The prism angle is $117^\circ 48'$. Also compact, in botryoidal, reniform, and globular masses, often showing a lamellar or radial fibrous structure.

Imperfect prismatic cleavage. Uneven fracture. Brittle. Hardness 3.5 to 4. Specific gravity 4.2 to 4.35. Colorless, white, gray, or yellow white. Streak white. Vitreous luster, on fracture surfaces somewhat greasy. Translucent.

BaCO_3 . Easily fusible, imparts a green color to the flame. Readily soluble in dilute hydrochloric acid. Precipitated from solution by sulphuric acid.

Occurs in large quantities with deposits of galena in northwestern England, thus, at Fallowfield, near Hexham, Northumberland; Dufton, Westmoreland; Alston Moor, Cumberland. Otherwise, witherite is not very common. With barite at Freiberg, Saxony; Lexington, Kentucky; also in the Thunder Bay district, Lake Superior.

Witherite is used to adulterate white lead and in the extracting of sugar from sugar-beets. In 1908 the importation of witherite into the United States was valued at \$22,159.

TARNOWITZITE, $(\text{Ca,Pb})\text{CO}_3$.

Orthorhombic, bipyramidal class. $a : b : c = 0.6220 : 1 : 0.7168$. This is an isomorphous mixture of CaCO_3 and PbCO_3 . The amount of PbCO_3 present may be as high as 9%. Crystals are sometimes rather complicated; generally pyramidal in habit. Often twins, trillings, and even cyclic twelvings. White or green in color. Specific gravity 2.99. Occurs in the Friedrich mine, near Tarnowitz, Silesia.

CERUSSITE, Cerusite, White Lead Ore, PbCO_3 .

Orthorhombic, bipyramidal class. $a : b : c = 0.6101 : 1 : 0.7229$. Crystals are generally tabular, prismatic, or pyramidal in habit. Often arranged in clusters or star-shaped groups. Many forms have been observed and the crystals are sometimes rather complex. Pseudo-hexagonal symmetry due to a prismatic angle of $117^\circ 14'$. Twins are very common and similar to those of aragonite, page 119. The twinning plane is usually a plane parallel to the unit prism. Penetration trillings according to this law form stellate groups. A second twinning law with the twinning plane parallel to the brachyprism, $n = 3$, is not very common. Also compact, in granular and, more rarely, fibrous masses; reniform, stalactitic, in crusts, and earthy.

Distinct prismatic and brachydomatic cleavages. Conchoidal fracture. Brittle. Hardness 3 to 3.5. Specific gravity 6.4 to 6.6. Colorless, white,



gray, yellow, brown, blue, green, and black. Streak white. Greasy or resinous luster. Transparent to translucent.

PbCO_3 . At times contains silver and zinc. A variety from Mt. Ponì, Iglesias, Sardinia, containing 7% ZnCO_3 , is termed *iglesiasite*. May contain admixtures of galena and organic matter. Fuses easily, decrepitates, and yields a lead coating; also a globule of lead. Is soluble in nitric acid with effervescence, in hydrochloric and sulphuric acids with a white residue. Occurs as a pseudomorph after galena and anglesite.

Occurs commonly in the upper levels of galena deposits, from which it has resulted by the action of carbonated waters. Anglesite, PbSO_4 , is often an intermediate product. Found at Clausthal, Hartz Mts.; Johanngeorgenstadt, Saxony; Mies and Příbram, Bohemia; Friedrichsseggen and Ems, Nassau; Broken Hill, New South Wales, with ores of copper and silver; Leadhills, Scotland; Leadville, Colorado, formerly in great quantities; Pima and Yuma counties, Arizona; Park City, Utah.

Cerussite is an important ore of lead and silver.

BARYTOCALCITE, $\text{BaCO}_3 \cdot \text{CaCO}_3$.

Monoclinic, prismatic class. $a : b : c = 1.1201 : 1 : 0.8476$, $\beta = 102^\circ 26'$. Small prismatic crystals, also in granular aggregates. Prismatic and basal pinacoidal cleavages. Hardness 4. Specific gravity 3.65. Yellow white in color. Vitreous luster. Translucent.

$\text{BaCO}_3 \cdot \text{CaCO}_3$. Considered a double salt. The two carbonates are always present in the same ratio, namely, 1 : 1. Occurs with alstonite, barite, and fluorite at Alston Moor, Cumberland; also Langban, Sweden.

B. BASIC CARBONATES

MALACHITE GROUP

This group includes the basic carbonates of copper, zinc, and lead.

MALACHITE, $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$. Monoclinic Prismatic Class

AZURITE, $2\text{CuCO}_3 \cdot \text{Cu(OH)}_2$. Monoclinic Prismatic Class

HYDROCERUSSITE, $2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$. Dihexagonal Bipyramidal Class

HYDROZINCITE, $\text{ZnCO}_3 \cdot 2\text{Zn(OH)}_2$. ?

AURICHALCITE, $2(\text{Zn.Cu})\text{CO}_3 \cdot 3(\text{Zn.Cu})(\text{OH})_2$. Monoclinic Prismatic Class

The chemical and crystallographical properties of the members of this group vary so greatly that no definite relationship can be pointed out.

MALACHITE, Green Carbonate of Copper, $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$.

Monoclinic, prismatic class. $a : b : c = 0.7823 : 1 : 0.4036$, $\beta = 90^\circ 3'$. Crystals are usually acicular, very slender, and without good terminations. Often arranged in groups and tuffs. Vertically striated. The unit prism and the three pinacoids are the forms commonly observed. Twins are rather common, the twinning plane being parallel to the orthopinacoid. Commonly in reniform, botryoidal, and stalactitic aggregates with smooth surfaces and banded or radial fibrous structure. Also earthy and in crusts.

Perfect basal and clinopinacoidal cleavages. Conchoidal fracture. Brittle. Hardness 3.5 to 4. Specific gravity 3.7 to 4.1. Bright emerald green, grass green to nearly black in color. Light green streak. Translucent to opaque. Adamantine, silky, or dull luster.

$\text{CuCO}_3 \cdot \text{Cu(OH)}_2$. Crystals are usually quite pure. Compact masses may be mixed with clay, the oxides of iron and manganese, silica, etc. Fuses easily, colors the flame green, and yields a globule of copper. Yields water and carbon dioxide in a closed tube. Effervesces with acids. Occurs commonly as a pseudomorph, especially after cuprite, atacamite, azurite, tetrahedrite, chalcopyrite, calcite, cerussite, etc.

Malachite is a common alteration product of copper minerals, usually the result of the action of carbonated waters. Hence, it is found in smaller or greater quantities in the upper levels of all copper mines. In the Ural Mts. it occurs in large quantities; Chessy, France, pseudomorphs after cuprite; Cornwall, England; various places in the Hartz Mts.; Chile; Australia. Formerly in magnificent specimens in the Bisbee and Clifton Copper districts of Arizona, especially the Detroit and Manganese Blue mines; Park City, Utah; as a coating on native copper in the Lake Superior Copper region; also in Amelia Co., Virginia, etc.

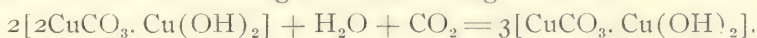
Malachite is used as an ore of copper. Also in jewelry and for ornamental purposes, such as table tops, vases, etc.

AZURITE, Chessylite, Blue Carbonate of Copper, $2\text{CuCO}_3 \cdot \text{Cu(OH)}_2$.

Monoclinic, prismatic class. $a : b : c = 0.8501 : 1 : 1.7611$, $\beta = 92^\circ 24'$. Crystals are generally short prismatic or thick tabular, and arranged in spherical aggregates. Often very complex. Common forms are the unit prism, unit negative pyramid, basal pinacoid, and the clinodome with m equal to $1/3$. Twins are not common, the twinning plane is parallel to the orthodome with the coefficient m equal to $1/2$. Usually compact; in reniform and botryoidal masses, often with a velvety, radial fibrous structure; also earthy and in crusts.

Distinct clinodomatic cleavage. Conchoidal to uneven fracture. Brittle. Hardness 3.5 to 4. Specific gravity 3.7 to 3.83. Vitreous to adamantine luster. Light azure to deep blue in color. Streak light blue. Translucent to opaque.

$2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$. Chemical reactions same as for malachite, page 124. Occurs as a pseudomorph after cuprite, tetrahedrite, and dolomite. Alters to malachite according to the following reaction:



Formation and occurrences same as for malachite. Excellent crystals occur at Chessy, France; Cornwall, England; Ural Mts.; Chile; Australia; Bisbee and Clifton Copper districts, Arizona; also in Utah, California, etc.

An ore of copper. Paint made from azurite turns green in time, due to an alteration to malachite, see above.

HYDROCERUSSITE, $2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$.

Hexagonal, dihexagonal bipyramidal class. $a : c = 1 : 1.4187$. Occurs as colorless plates on native lead at Langban, Sweden; with galena at Wanlockhead, Scotland.

HYDROZINCITE, Zinc Bloom, $\text{ZnCO}_3 \cdot 2\text{Zn}(\text{OH})_2$.

Crystal form is unknown. Only in compact, earthy, or fibrous masses; sometimes reniform, stalactitic, or in crusts. Somewhat brittle. Hardness 2 to 2.5. Specific gravity 3.25 to 3.8. Color is snow white to yellowish. Vitreous luster.

$\text{ZnCO}_3 \cdot 2\text{Zn}(\text{OH})_2$. Composition is not constant. Hydrozincite is an alteration product of zinc minerals. Hence, is found with hemimorphite, smithsonite, sphalerite, etc. Occurs at Bleiberg and Raibl, Carinthia; various places in the province of Santander, Spain; Sardinia; Algeria; Friedensville, Penna; Linden, Wis.

AURICHALCITE, $2(\text{Zn.Cu})\text{CO}_3 \cdot 3(\text{Zn.Cu})(\text{OH})_2$.

Monoclinic, prismatic class. $a : b : c = ? : 1 : 1.657$, $\beta = 84^\circ 15'$. Acicular crystals, also rosette aggregates. Hardness 2. Pale green to sky-blue in color. Pearly luster. Translucent. May contain as much as 8% CaCO_3 , and is then known as *buratite*. Occurs with limonite and calcite at Loktewsk, Altai, Siberia; Chessy, France; Lancaster, Penna.; Santa Caterina Mts., Arizona; Beaver Co., Utah.

DAWSONITE, $\text{Na} \cdot \text{Al}(\text{OH})_2\text{CO}_3$. Occurs in thin lamellar, and fibrous aggregates. White in color. Vitreous luster. Specific gravity 2.40. Found in a feldspathic dike at Montreal, Canada; also in a cinnabar-bearing dolomite in Tuscany.

BISMUTITE, probably $\text{Bi}_2\text{CO}_3 \cdot \text{H}_2\text{O}$. Occurs in crusts; earthy; amorphous. Dirty green or yellow in color. Found at Schneeberg and Johanngeorgenstadt, Saxony; Gaston Co., N. C.; Brewer's Mine, S. C.

PHOSGENITE, Corneous Lead, $(\text{PbCl})_2\text{CO}_3$.

Tetragonal, $a : c = 1 : 1.0876$. Short prismatic or acute pyramidal crystals. Common forms are the prisms of the first and second orders, unit and modified ($m = 3/2$ and 8) bipyramids, and the basal pinacoid. Prismatic cleavages. Conchoidal fracture. Somewhat sectile. Hardness 2.5 to 3. Specific gravity 6 to 6.3. Greasy adamantine luster. Color white, gray, or yellow. White streak. Transparent to translucent.

$(\text{PbCl})_2\text{CO}_3$. This is a chlorocarbonate of lead. Easily fusible. Yields on charcoal a globule of lead. Soluble with effervescence in dilute nitric acid.

Commonly associated with galena. Has resulted from the alteration of galena. Occurs at Mt. Poni and Gibbas, Sardinia; Matlock, Derbyshire; with cerussite at Tarnowitz, Silesia; on ancient lead slags at Laurium, Greece.

NORTHUPITE, $\text{MgCO}_3 \cdot \text{Na}_2\text{CO}_3 \cdot \text{NaCl}$. White, yellow, or gray octahedrons. Hardness 3.5 to 4. Specific gravity 2.4. Very brittle. Decomposed by hot water with a separation of magnesium carbonate. Occurs sparingly in clay at Borax Lake, San Bernardino Co., California.

C. HYDRATED CARBONATES

No isomorphous groups have as yet been noted among the hydrated carbonates.

THERMONATRITE, $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$.

Orthorhombic, bipyramidal class. $a : b : c = 0.3644 : 1 : 1.2254$. Rectangular plates. Generally as a fibrous or earthy efflorescence. Brachypinacoidal cleavage. Hardness 1.5. Specific gravity 1.5 to 1.6. Colorless. Occurs in the soda lakes of Egypt and East India; also as an efflorescence in arid regions.

Natron, Soda, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 1.4186 : 1 : 1.4828$, $\beta = 122^\circ 20'$. Artificial crystals are usually tabular, somewhat similar to those of gypsum, page ???. They consist of the unit prism, clinopinacoid, and the negative unit pyramid. In nature natron occurs only in crystalline crusts or as an earthy efflorescence. Clino- and orthopinacoidal cleavages. Conchoidal fracture. Hardness 1 to 1.5. Specific gravity 1.4 to 1.5. Colorless, gray or yellow white. Vitreous luster. Transparent to translucent.

$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$. When heated, it melts in its water of crystallization. Easily soluble in water. On exposure to air loses water of crystallization and alters to thermonatrite, $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$.

Occurs in the soda lakes of Egypt, and North and South America.

Also as an efflorescence in arid regions, and in small quantities on the lavas of Aetna, Vesuvius, etc.

The artificial compound is used extensively in glass and soap manufacture, washing powders, etc.

Trona, Urao, $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 2.8459 : 1 : 2.9696$, $\beta = 102^\circ 37'$. Tabular, fibrous, or columnar crystals. The common forms are the basal and orthopinacoids, and the positive unit pyramid. Generally in crystalline crusts. Perfect orthopinacoidal cleavage. Hardness 2.5 to 3. Streak white. Specific gravity 2.1 to 2.2. Colorless, gray or yellow white. Translucent. Vitreous luster. Alkaline taste.

$\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$. Usually mixed with some NaCl and Na_2SO_4 . Easily soluble in water. Does not effloresce. Yields much water in a closed tube. Effervesces with acids. Colors flame an intense yellow.

Occurs in the province of Fezzan, Africa, where it is used to some extent for building purposes; in the soda lakes of Egypt, East Indies, and Venezuela. Also in Churchill Co., Nevada; Borax Lake, San Bernardino Co., and Owen's Lake, Inyo Co., California.

PIRSSONITE, $\text{Na}_2\text{CO}_3 \cdot \text{CaCO}_3 \cdot 2\text{H}_2\text{O}$.

Orthorhombic, pyramidal class. $a : b : c = 0.5662 : 1 : 0.3019$. Hemimorphic crystals. Colorless to cloudy white. Vitreous luster. Brittle. Hardness 3 to 3.5. Specific gravity 2.35. Soluble with effervescence in cold dilute acids. Occurs in clay in Borax Lake, San Bernardino Co., California.

GAY-LUSSITE, $\text{Na}_2\text{CO}_3 \cdot \text{CaCO}_3 \cdot 5\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 1.4897 : 1 : 1.4442$, $\beta = 101^\circ 33'$. Columnar or wedge-shaped crystals. Colorless, white, gray, or yellow. Prismatic cleavage. Conchoidal fracture. Hardness 2 to 3. Specific gravity 1.9 to 1.95. Transparent to translucent. Streak white or grayish. Vitreous luster.

$\text{Na}_2\text{CO}_3 \cdot \text{CaCO}_3 \cdot 5\text{H}_2\text{O}$. Soluble with effervescence in acids. Partially soluble in water, Na_2CO_3 may be thus readily extracted. Fuses to a white enamel. Colors flame yellow. Occurs at Lagunilla, Venezuela; Soda Lake, near Ragtown, Nevada. The artificial compound is produced on a large scale in the Leblanc process for the manufacture of sodium carbonate.

HYDROMAGNESITE, $3\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$. Monoclinic, prismatic class. $a : b : c = 1.0379 : 1 : 0.4652$, $\beta = 90^\circ$ (approximately). Has been considered orthorhombic. Small, indistinct acicular crystals. Sometimes arranged in radial groups; also in crusts. Snow-white in color. Earthy to imperfect conchoidal fracture. Hardness

1.5 to 2. Specific gravity 2.15. Is an alteration product of serpentine. Occurs at Hoboken, N. J.; Texas, Penna.; Hrubtschitz, Moravia; Kraubat, Styria. *Predassite* and *pencatite* are crystalline limestones, mixed with hydromagnesite and periclase, and occur at Predazzo, Tyrol.

ZARATITE, Emerald Nickel, Texasite, $\text{NiCO}_3 \cdot 2\text{Ni(OH)}_2 \cdot 4\text{H}_2\text{O}$. Crystallization is unknown. Usually in fine crystalline, warty crusts. Sometimes compact and massive. Hardness 3. Specific gravity 2.57 to 2.69. Translucent. Subvitreous luster. Occurs on chromite at Texas, Lancaster Co., Penna.; Island of Unst, Scotland; Tasmania; Spain.

3. MANGANITES AND PLUMBITES

The two acids of manganese, H_2MnO_3 and H_4MnO_4 , and the orthoplumbous acid, H_4PbO_4 , form compounds which are of considerable importance as minerals.

BRAUNITE GROUP

This group includes the manganese and iron salts of the manganous acid H_2MnO_3 .

	$a : c$
BRAUNITE, MnMnO_3 . Ditetragonal Bipyramidal Class	1 : 0.9922
BIXBYITE, FeMnO_3 . Cubic, Hexoctahedral Class	

BRAUNITE, MnMnO_3 .

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.9922$. Tetragonal bipyramids simulating the octahedron of the cubic system. Crystals are usually very small and arranged in drusy crusts. Commonly the unit tetragonal bipyramid occurs alone, sometimes with the basal pinacoid and the ditetragonal bipyramid with coefficients n and m equal to 2 and 4, respectively. Twins are not common. Twinning plane is parallel to the prism of the second order. Also in granular aggregates.

Perfect pyramidal cleavage. Uneven fracture. Brittle. Hardness 6 to 6.5. Specific gravity 4.75 to 4.9. Greasy metallic luster. Opaque. Brown to iron black in color. Brownish black streak.

MnMnO_3 . Usually contains some silica and barium oxide. *Marceline* is a variety with from 7 to 15% of silica. Infusible. Evolves chlorine when treated with hydrochloric acid. Imparts an amethystine color to the borax bead.

Occurs with other ores of manganese, magnetite, and hematite at Ilmenau, Thuringia; Ilfeld, Hartz Mts.; St. Marcel, Piedmont; in large quantities at Jakobsberg and elsewhere in Sweden; India; near Batesville, Arkansas.

An ore of manganese.

BIXBYITE, FeMnO_3 . Cubic. Occurs in small cubes. Black in color. A portion of the iron may be replaced by magnesium and manganese, the manganese by titanium. Occurs with topaz and decomposed manganese garnets (spessartite) in rhyolite in Utah.

HAUSMANNITE GROUP

Here are placed the manganese and lead salts of the ortho acid having the general formula H_4RO_4 , where R may be either manganese or lead.

HAUSMANNITE, Mn_2MnO_4 . Tetragonal Scalenohedral Class $a : c = 1 : 1.1573$
MINIUM, Pb_2PbO_4 . ?

HAUSMANNITE, Mn_2MnO_4 . Tetragonal, scalenohedral class. $a : c = 1 : 1.1573$. Crystals are apparently holohedral and possess a bipyramidal habit. The bipyramids are more acute than those of braunite. Crystal faces are often striated horizontally. The common form is the unit bipyramid of the first order; more rarely the modified bipyramid with the coefficient m equal to $1/3$, and the prism of the second order. Twins are common. Twinning plane is parallel to the prism of the second order. Cyclic fivelings according to this law are not uncommon. They resemble large bipyramids with furrowed edges. Also in granular masses.

Perfect basal cleavage. Uneven fracture. Hardness 5 to 5.5. Specific gravity 4.7 to 4.8. Greasy metallic luster. Brownish black in color. Brown streak.

Mn_2MnO_4 . Infusible. Soluble in hydrochloric acid with an evolution of chlorine.

Usually associated with braunite and other manganese minerals. Occurs at Ilfeld, Hartz Mts.; Ilmenau, Thuringia; Pajsberg, Nordmarken, Langban, and elsewhere in Sweden.

MINIUM, Pb_2PbO_4 . Crystalline form unknown. Occurs only in powdery or crystalline scales or masses. Hardness 2 to 3. Specific gravity 4.6. Opaque. Dull or faint greasy luster. Bright red in color. Streak orange yellow. On charcoal yields globule and characteristic coating of lead. Occurrences in nature are doubtful. Minium is formed when lead ores are roasted, and, hence, is sometimes observed as a pseudomorph after galena and cerussite. Found at Bleialf in the Eifel, Prussia; Badenweiler, Baden; Austin, Wythe Co., Va.; Leadville, Colo.

CHALCOPHANITE, $(Zn,Mn)Mn_2O_5 \cdot 2H_2O$. Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 3.527$. Small tabular crystals; also foliated aggregates and stalactitic. Hardness 2.5. Specific gravity 3.9. Bluish to iron black in color. Chocolate brown streak. Metallic luster. An alteration product of franklinite. Occurs with franklinite at Sterling Hill, Sussex Co., N. J. In *hydrofranklinite* iron replaces a portion of the manganese.

Psilomelane, Black Hematite.

Occurs only in botryoidal, reniform, or stalactitic masses, usually with a smooth surface and at times with an apparently fine fibrous structure. Dark gray to iron black in color. Brownish black streak. Dull or sub-metallic luster. Hardness 5 to 6. Specific gravity 3.7 to 4.7. Brittle. Opaque.

It is doubtful whether psilomelane is an independent mineral or not. It is often considered a manganite of manganese with considerable barium replacing manganese. Usually contains 6 to 17% of barium oxide, 1 to 6%

water, and varying amounts of the oxides of potassium, calcium, cobalt, copper, aluminium, silicon, etc. Infusible. Evolves chlorine when treated with hydrochloric acid. Reacts for manganese and barium.

Occurs with other manganese ores, limonite, barite, etc. Found at Ilfeld, Hartz Mts.; Ilmenau, Thuringia; Devonshire, and Cornwall, England; Brandon and elsewhere, Vermont; Virginia; Independence Co., Arkansas.

One of the most common ores of manganese. Uses are the same as for pyrolusite, page 82.

WAD. Compact, earthy masses of a dark brown or black color. Often soils the fingers, may, however, possess the hardness 6. Specific gravity 3 to 4.3. When soft, it is usually loosely compact. Brown streak. Composition varies greatly. Is a mixture of the various manganese minerals. Contains 5 to 14% of water and, in general, the same impurities as psilomelane. The amount of manganese varies from 15 to 40%. Wad is used as an ore of manganese, and in the manufacture of chlorine and paint.

VI. SULPHATES, CHROMATES, MOLYB- DATES, TUNGSTATES, AND URANATES

1. NORMAL SULPHATES AND CHROMATES

The minerals of this section are normal anhydrous salts of sulphuric and chromic acids, and may be readily divided into several isomorphous groups.

GLASERITE GROUP

This group includes the normal anhydrous sulphates of potassium, sodium, and ammonium. The sulphate of potassium and sodium is dimorphous. The group may, hence, be divided into two series, as follows:

HEXAGONAL SERIES

		$a : c$
GLASERITE, $(K,Na)_2SO_4$.	Ditrigonal Scalenohedral Class	1 : 1.2879

ORTHORHOMBIC SERIES

		$a : b : c$
ARCANITE, $(K,Na)_2SO_4$.	Bipyramidal Class	1.7462 : 1 : 1.3033
MASCAGNITE, $(NH_4)_2SO_4$.	Bipyramidal Class	1.7722 : 1 : 1.2954
THENARDITE, Na_2SO_4 .	Bipyramidal Class	1.7910 : 1 : 1.2541

The elements of crystallization given for arcanite and mascagnite are for artificial crystals.

GLASERITE, $(K,Na)_2SO_4$.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.2879$. Colorless, tabular crystals. Unit prism predominates. Crystals are often arranged in groups resembling aragonite trillings. Vitreous luster. Transparent to translucent. Bitter saline taste. May contain as high as 40% of Na_2SO_4 . Occurs with halite at Stassfurt, Germany, and Racalmuto, near Girgenti, Sicily; also in the lavas of Vesuvius.

ARCANITE, $(K,Na)_2SO_4$. Orthorhombic, bipyramidal class. $a : b : c = 1.7462 : 1 : 1.3033$. This modification has not as yet been observed in nature. The artificial crystals show a pseudo-hexagonal development.

MASCAGNITE, $(NH_4)_2SO_4$.

Orthorhombic, bipyramidal class. $a : b : c = 1.7722 : 1 : 1.2954$. In nature it occurs only as crusts and stalactites. Colorless, white, or yellow. Pungent taste, slightly bitter. Hardness 2 to 2.5. Specific gravity 1.7 to 1.8. Occurs in the lavas of Aetna, Vesuvius, etc.

THENARDITE, Na_2SO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 1.7910 : 1 : 1.2541$. Acute pyramidal, short prismatic, or tabular crystals. Also in twinned crystals, the twinning plane is parallel to the unit prism. Most commonly in crystal aggregates and crystalline crusts.

Brachypinacoidal cleavage. Uneven fracture. Hardness 2.5. Specific gravity 2.68. Colorless to brown. Transparent. When exposed to air it becomes covered with a white crust. Easily soluble in water.

Usually found in salt and borax lakes, thus, in the deserts of Chile, Peru, and Bolivia; Lake Balkasch, Central Asia; Borax Lake, San Bernardino Co., California; Rio Verde, Yavapai Co., Arizona.

APHTHITALITE is according to von Groth a mixture of glaserite and arcanite.

GLAUBERITE GROUP

This group includes three double sulphates of sodium, potassium, calcium, and magnesium.

Glauberite, $\text{Na}_2\text{SO}_4 \cdot \text{CaSO}_4$.

Monoclinic Prismatic Class

VAN'T HOFFITE, $3\text{Na}_2\text{SO}_4 \cdot \text{MgSO}_4$.

?

LANGBEINITE, $\text{K}_2\text{SO}_4 \cdot 2\text{MgSO}_4$.

Tetrahedral Pentagonal Dodecahedral Class

These double sulphates are very unstable compounds.

Glauberite, $\text{Na}_2\text{SO}_4 \cdot \text{CaSO}_4$.

Monoclinic, prismatic class. $a : b : c = 1.2209 : 1 : 1.0270$, $\beta = 112^\circ 11'$. Crystals are generally thick tabular, the basal pinacoid predominating. The common forms are the basal and orthopinacoids, unit prism, and the negative unit hemi-pyramid. Occurs also in reniform and lamellar masses.

Perfect basal cleavage. Conchoidal fracture. Hardness 2.5 to 3. Specific gravity 2.7 to 2.85. Brittle. Vitreous to greasy luster. Colorless, white, gray, yellow, also flesh to brick red. White streak. Bitter saline taste.

$\text{Na}_2\text{SO}_4 \cdot \text{CaSO}_4$. Fuses easily. When dissolved in water, gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, is precipitated. Exposed to moist air the surface becomes coated with a crust of mirabilite, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$.

Glauberite is commonly associated with thenardite, mirabilite, halite, etc. It occurs at Villar Rubia, Spain; Vic, Lorraine, Western Germany; Berchtesgaden, Bavaria; Stassfurt, Germany; Austria; Sicily; Peru; Chile. In the United States glauiberite is found in the Rio Verde Valley, Arizona; Borax Lake, San Bernardino Co., California.

VAN'T HOFFITE, $3\text{Na}_2\text{SO}_4 \cdot \text{MgSO}_4$. Crystallization unknown. Colorless. Pearly luster. Uneven fracture. Saline taste. Occurs with langbeinite in the salt deposits of the Stassfurt district, Germany.

LANGBEINITE, $K_2SO_4 \cdot 2MgSO_4$. Cubic, tetrahedral pentagonal dodecahedral class. Crystals are usually tetrahedral in habit, sometimes very complex. Generally in granular aggregates. Colorless. Greasy luster. Hardness 3 to 4. Specific gravity 2.83. Exposed to moist air it becomes cloudy, due to the absorption of water. Easily soluble in hydrochloric acid, less so in water. Occurs in the salt deposits of the Stassfurt district of Germany.

BARITE GROUP

The normal anhydrous sulphates and chromates of calcium, strontium, barium, and lead are placed in this group. The group consists of two series.

ORTHORHOMBIC SERIES

		a	:	b	:	c
ANHYDRITE, $CaSO_4$.	Bipyramidal Class	0.8932	:	1	:	1.0008
CELESTITE, $SrSO_4$.	Bipyramidal Class	0.7809	:	1	:	1.2832
BARTOCELESTITE, $(Sr, Ba)SO_4$.	Bipyramidal Class	0.7666	:	1	:	1.2534
BARITE, $BaSO_4$.	Bipyramidal Class	0.8146	:	1	:	1.3119
ANGLESITE, $PbSO_4$.	Bipyramidal Class	0.7852	:	1	:	1.2894

MONOCLINIC SERIES

Crocoite, $PbCrO_4$. Prismatic Class 0.9603 : 1 : 0.9171, $\beta = 102^\circ 33'$.

Anhydrite is sometimes considered as not being strictly isomorphous with celestite, barite, and anglesite. However, on account of its related form and chemical composition it has been included in the orthorhombic series.

ANHYDRITE, $CaSO_4$.

Orthorhombic, bipyramidal class. $a : b : c = 0.8932 : 1 : 1.0008$. Crystals, which are not very common, are usually prismatic (Figure 69) or thick tabular in habit. The forms generally observed are the unit macro- and brachydomes (r and s), and the brachypinacoid (b). The three pinacoids predominate on thick tabular crystals. Polysynthetic twins are rather common, the twinning plane is parallel to the unit macrodome. Occurs most commonly in cleavable masses; also fibrous, granular, lamellar, compact, and reniform.

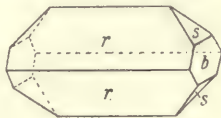


FIG. 69.

Cleavage in three directions at right angles. Very perfect cleavage and pearly luster parallel to the basal pinacoid; perfect cleavage and vitreous luster parallel to the brachypinacoid, and distinct cleavage with a greasy vitreous luster parallel to the macropinacoid. Conchoidal fracture.

Brittle. Hardness 3 to 3.5. Specific gravity 2.8 to 3. Transparent to translucent. Luster on massive varieties is vitreous to pearly. Color may be white, grayish, bluish, reddish, or black. Streak white. Massive varieties resemble marble or lumps of sugar.

CaSO_4 . Often mixed with bituminous matter. Fuses to a white enamel. Imparts a reddish color to the flame. Fine powder is soluble in concentrated sulphuric acid. Absorbs water and alters to gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, causing a large increase in volume. This increase is estimated to be from 33 to 62% of the original volume. This hydration is, no doubt, the cause of the many local disturbances in the rock strata commonly noticed in regions where gypsum occurs. Sometimes anhydrite occurs as a pseudomorph after gypsum.

Occurs commonly in limestones and shales associated with halite and gypsum. Some of the principal localities are the Stassfurt district of Germany, page 100; Hall, Tyrol; Bex, Switzerland; Kapnik, Hungary; Wieliczka, Galicia; Berchtesgaden, Bavaria; Lockport, N. Y.; near Philadelphia, Pa.; Nashville, Tenn.; Detroit, Mich.; also in large deposits in Nova Scotia and New Brunswick.

Anhydrite is of little use commercially. A silicious variety is sometimes cut and polished for ornamental purposes.

CELESTITE, SrSO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.7809 : 1 : 1.2832$. Crystals are common, either prismatic (Figure 70), or tabular (Figure 71),

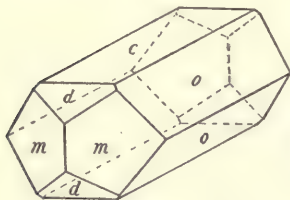


FIG. 70.

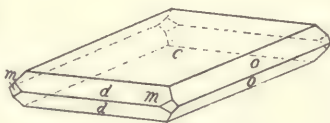


FIG. 71.

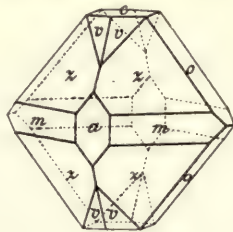


FIG. 72.

in habit; rarely pyramidal (Figure 72). The common forms are the unit prism m , unit brachydome o , basal pinacoid c , and the modified macrodome d with the coefficient m equal to $\frac{1}{2}$. Occurs also in fibrous and cleavable masses; more rarely granular, concretionary, globular, or earthy.

Perfect basal and good prismatic cleavages. The prism angle is $104^\circ 10'$. Uneven fracture. Hardness 3 to 3.5. Specific gravity 3.9 to 4. Vitreous to pearly luster, on fracture surfaces somewhat greasy. White.

streak. Generally possesses a faint blue tinge, may be white, yellow, more rarely green or reddish.

SrSO_4 . Sometimes very pure, but may contain small percentages of calcium and barium. Fuses to a white enamel. Imparts a crimson color to the flame. Insoluble in acids. More soluble in water than barite.

Celestite is usually associated with sulphur, gypsum, halite, and occasionally galena and sphalerite. There are two principal types of occurrences.

(1) *Disseminated* in shales, limestones, and dolomites. The dissemination may be in the form of well developed crystals or as irregular particles of varying sizes. When such celestite-bearing rocks are acted upon by circulating water the celestite is dissolved and the so-called *gashed*, *acicular*, and *vermicular* limestones and dolomites of New York and Michigan result. These rocks, as the terms imply, are more or less porous. This method of occurrence of celestite is doubtless more widespread than has hitherto been supposed.

(2) In *cracks* and *cavities* in rocks of varying ages but principally of sedimentary origin. Here celestite is a secondary formation, having been derived from the overlying and adjoining celestite-bearing rocks by the action of circulating water. Most of the best known localities for the occurrence of celestite are of this type. Celestite is found in association with sulphur and gypsum in the Girgenti Sulphur district of Sicily, also at Maybee, Monroe Co., and elsewhere in Southern Michigan, see page 14. With halite it occurs at Stassfurt, Germany; Bex, Switzerland, etc. In excellent crystals, some of which are 18 inches in length, in the Crystal Cave on the Island of Put-In-Bay, in Lake Erie; also on Drummond Island in Lake Huron; in Jefferson, Schoharie, and Oneida Counties, New York; at Cedar Cliff, Mineral Co., West Virginia; Burnet, Burnet Co., Texas; Larimer Co., Colorado; Kingston, Canada; and San Bernardino Co., California. Fibrous varieties occur at Dornburg, near Jena, Germany; Bell's Mills, Blair Co., Pa.; and near Montreal, Canada. A red variety is found in Brown Co., Kansas.

Celestite is used to a small extent in the manufacture of strontium compounds. Strontianite is, however, preferred, see page 121.

BARTOCELESTITE, $(\text{Sr}, \text{Ba}) \text{SO}_4$, is an isomorphous mixture of the sulphates of strontium and barium. Crystals are rare. Usually occurs in radial fibrous aggregates or earthy masses in limestone and marl. Hardness 2.5. Specific gravity 4.1 to 4.2. Found at Greiner and in the Binnenthal, Tyrol; Drummond Island, Lake Huron, etc.

BARITE, Heavy Spar, Barytes, BaSO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.8146 : 1 : 1.3119$. Crystals are common and usually well developed. Over 120 forms have

been observed. Tabular (Figures 73 and 74), and prismatic (Figures 75 and 76), habits are very common. The forms usually observed are the unit prism m , modified ($m = \frac{1}{2}$) macrodome d , unit brachydome o , and the basal pinacoid c . Tabular crystals are often arranged in crested divergent groups. Also in lamellar, fibrous, globular, granular, earthy, stalactitic, and nodular masses.

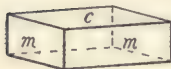


FIG. 73.

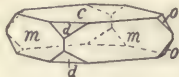


FIG. 74.

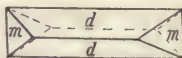


FIG. 75.



FIG. 76.

Perfect basal and prismatic cleavages. The prism angle is $101^{\circ}37\frac{1}{2}'$. Uneven fracture. Brittle. Vitreous to pearly luster, somewhat greasy on fracture surfaces. Transparent to opaque. Colorless, white, yellow, gray, blue, brown, or red. White streak. Hardness 2.5 to 3.5. Specific gravity 4.3 to 4.7.

BaSO_4 . May contain varying amounts of the oxides of strontium and calcium, also silica, clay, or bituminous matter. Occasionally the amount of strontium oxide present may be as high as 12%. Fuses with difficulty. The fused mass reacts alkaline. Reacts easily for sulphur with soda on charcoal. Insoluble in hydrochloric acid. Powdered barite is soluble in warm concentrated sulphuric acid. Imparts a green color to the flame.

In general barite occurs in two ways, viz: (1) *With metalliferous veins*, usually associated with galena, sphalerite, fluorite, chalcopyrite, cobalt and nickel minerals, manganese ores, etc. Most of the finest crystals are in ore deposits of this character. This type of occurrence of barite is very widespread but of no commercial importance. (2) *In pockets and lenticular deposits*, principally in limestones. The pockets may vary from 100 to 200 or more feet in width and in some instances have been traced for several miles. This type of occurrence furnishes practically all the barite of commerce. The principal producing localities in the United States are in Washington, Miller, and Cole Counties, Missouri; Bradley, Monroe, London, Cooke, and Greene Counties, Tennessee; Bedford, Pittsylvania, Campbell, and Tazewell Counties, Virginia; Madison and Gaston Counties, North Carolina. In 1907 the United States produced 89,621 tons of barite, valued at \$291,777. This production was obtained, in the order given, from the states named above. Some barite is imported from Germany and New Foundland. Cleaned, bleached, and ground barite is worth from \$7.00 to \$12.00 per ton. Crude barite averaged \$3.26 per ton in 1907.

Barite is used extensively in the manufacture of paper, rubber, paints,

pottery glazes, barium hydroxide, also to coat canvas ham sacks, and as an adulterant of white lead. Some varieties are used for ornamental purposes.

ANGLESITE, PbSO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.7852 : 1 : 1.2894$. Crystals are sometimes highly modified and may be short prismatic (Figure 77), tabular, or pyramidal (Figure 78), in habit. The forms, commonly observed, are the unit prism m , basal pinacoid c , unit bipyramid z , the brachybipyramid y with the coefficient n equal to 2, unit brachydome o , and the modified macrodome d with the coefficient m equal to $\frac{1}{2}$. These are similar to those noted on celestite and barite, pages 134 and 135. Also occurs in granular, compact, stalactitic, and nodular masses.

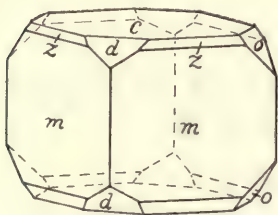


FIG. 77.

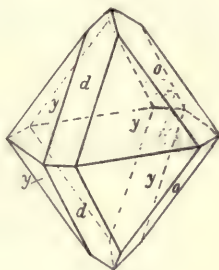


FIG. 78.

Distinct basal and prismatic cleavages. The prism angle is $103^\circ 43'$. Conchoidal fracture. Brittle. Hardness 3. Specific gravity 6.1 to 6.4. High adamantine luster, sometimes is resinous or greasy. Transparent to opaque. Colorless, white, yellow, brown, green, or blue. White streak.

PbSO_4 . Usually quite pure. Fuses easily in the candle flame. Reacts for lead and sulphur. Slightly soluble in nitric acid. Powdered anglesite is soluble in warm concentrated sulphuric acid. Is sometimes found as a pseudomorph after galena. Alters to cerussite.

Anglesite is a common oxidation product of lead minerals, especially galena. Hence, is usually found in cracks and cavities in galena. Excellent crystals are found at Mt. Ponì, Sardinia; Badenweiler, Black Forest; Clausthal, Hartz Mountains; Felsöbánya, Hungary; Anglesea, England; Leadhills, Scotland; Beresowsk, Ural Mountains; Phoenixville, Pa.; various places in Missouri, Wisconsin, Colorado, Utah, Arizona, California, etc.; in large deposits in Mexico and Australia.

Anglesite is an ore of lead.

Crocoite, PbCrO_4 .

Monoclinic, prismatic class. $a : b : c = 0.9603 : 1 : 0.9171$, $\beta = 102^\circ 33'$. Prismatic or acicular crystals are rather common. Many forms have been noted. Crystals are often highly modified. Prism faces are usually striated vertically. Occurs also in columnar and granular masses, sometimes in crusts.

Distinct basal and prismatic cleavages. Conchoidal to uneven fracture. Sectile. Hardness 2.5 to 3. Specific gravity 5.9 to 6.1. Translucent. Greasy adamantine luster. Various shades of hyacinth red, resembles potassium bichromate in color. Orange yellow streak.

PbCrO_4 . Fuses easily and on charcoal yields with deflagration metallic lead and a yellow coating. Imparts an emerald green color to the salt of phosphorous bead.

Crocoite is an alteration product of galena. It is usually associated with galena, pyrite, quartz, vanadinite, and wulfenite. Occurs at Beresowk, Murinski, and Nijni-Tagilak, Ural Mountains; Congonhas do Campo, Brazil; Island of Luzon in the Philippines; Dundas, Tasmania; Vulture district, Maricopa Co., Arizona.

Crocoite does not occur abundantly enough to be of commercial importance.

2. ANHYDROUS MOLYBDATES, TUNGSTATES, AND URANATES WOLFRAMITE GROUP

This group embraces the anhydrous molybdates and tungstates of calcium, lead, iron, and manganese. Depending upon crystallization two series—tetragonal and monoclinic—may be differentiated.

TETRAGONAL SERIES

		$a : c$
POWELLITE, CaMoO_4 .	Tetragonal Bipyramidal Class	1 : 1.5445
Wulfenite, PbMoO_4 .	Tetragonal Pyramidal Class	1 : 1.5777
Scheelite, CaWO_4 .	Tetragonal Bipyramidal Class	1 : 1.5315
STOLZITE, PbWO_4 .	Tetragonal Bipyramidal Class	1 : 1.5670

MONOCLINIC SERIES

		$a : b : c$	β
Huebnerite, MnWO_4 .	Prismatic Class	0.8362 : 1 : 0.8668	$90^\circ 52'$
WOLFRAMITE, $(\text{Fe}, \text{Mn})\text{WO}_4$.	Prismatic Class	0.8300 : 1 : 0.8678	$90^\circ 38'$
FERBERITE, FeWO_4 .	Prismatic Class	0.8229 : 1 : 0.8463	$90^\circ 20'$

The elements of crystallization of ferberite are for artificial crystals. Wolframite, hübnerite, and scheelite are of considerable importance commercially.

POWELLITE, CaMoO_4 .

Tetragonal system, tetragonal bipyramidal class. $a : c = 1 : 1.5445$. Small, acute pyramidal crystals and platy masses. Greenish yellow in color. Specific gravity 4.25. Sometimes is mixed with scheelite. Occurs in the Peacock mine, Western Idaho; Houghton Co., Mich.; as a pseudomorph after molybdenite at Barringer Hill, Llano Co., Texas; Nye Co., Nevada.

Wulfenite, PbMoO_4 .

Tetragonal system, tetragonal pyramidal class. $a : c = 1 : 1.5777$. Crystals are most commonly square and thin tabular in habit, also pyramidal (Figure 79), or short columnar. Tabular crystals are often arranged in groups. Hemimorphic development is not often observed. The common forms are the upper and lower tetragonal pyramids o and o' ; the tetragonal prism of the third order p with the coefficient n equal to $4/3$, and the lower basal pinacoid c . Also occurs in coarse or fine granular masses.

Fairly perfect pyramidal cleavage. Conchoidal to uneven fracture. Brittle. Hardness 3. Specific gravity 6.3 to 7. Resinous or adamantine luster. Transparent to translucent. The color may be various shades of yellow, green, gray, or red. Yellowish white streak.

PbMoO_4 . Lead may be partially replaced by calcium, molybdenum by chromium or vanadium. Decomposes and fuses easily. Yields on charcoal a globule of metallic lead. Decomposed by acids. Gives a blue solution with sulphuric acid and alcohol. Sometimes occurs as a pseudomorph after galena.

Wulfenite is a secondary mineral, the result of the decomposition of various lead ores. It is commonly associated with galena, pyromorphite, and vanadinite. Occurs at Bleiberg, Carinthia; Příbram and Rézbánya, Hungary; Freiberg district, Saxony; Phoenixville, Pa.; Tecomah mine, Utah; various places in Yuma, Maricopa, and Pinal Counties, Arizona; also in Wisconsin, Missouri and California.

Scheelite, CaWO_4 .

Tetragonal system, tetragonal bipyramidal class. $a : c = 1 : 1.5315$. Crystals are generally small, well developed, and pyramidal (Figure 80) in habit; rarely tabular. The common forms are the unit tetragonal bipyramids of the first and second orders p and e , and the tetragonal bipyramids of the third order h and s . On h the coefficient n is equal to 3, on s the values of n and m are both equal to 3. Contact and penetration twins with the twinning plane parallel to the prism of the second order are not uncommon. Occurs often as crystalline crusts on quartz; also in reniform, disseminated, or granular masses.

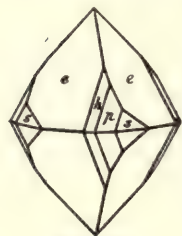


FIG. 80.

Distinct cleavage parallel to the unit bipyramid of the first order, less so parallel to the one of the second order. Conchoidal to uneven fracture. Hardness 4.5 to 5. Specific gravity 5.9 to

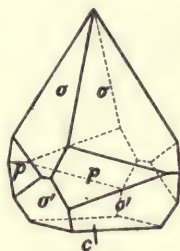


FIG. 79.

6.2. Greasy to adamantine luster. White streak. Transparent to opaque. Color white, yellow, gray, brown, green, or reddish.

CaWO_4 . Usually contains some molybdenum. In *cuproscheelite* copper replaces some of the calcium. Fuses with difficulty to a semi-transparent glass. Imparts to the salt of phosphorus bead in the reducing flame a green or yellow color when hot, blue when cold. Yields when treated by hydrochloric acid and metallic tin a deep blue precipitate. Decomposed by hydrochloric acid yielding a yellow precipitate of WO_3 , which is soluble in ammonium hydroxide. Occurs as a pseudomorph after wolframite.

Scheelite is a common alteration product of wolframite. It is usually found with the common associates of the *tin ore deposits*, page 81, namely, cassiterite, fluorite, topaz, apatite, molybdenite, wolframite, bismuth, and quartz. It occurs in Cornwall and Cumberland, England; Schlaggenwald and Zinnwald, Bohemia; Tyrol; Adelong, New South Wales; New Zealand; Tasmania; Beauce Co., Quebec.

In the United States scheelite occurs at Monroe and Trumbull, Conn.; Mecklenburg Co., N. C.; Jardine, Arizona; various places in Idaho and Colorado.

Scheelite is a source of tungsten and its compounds.

STOLZITE, PbWO_4 .

Tetragonal system, tetragonal bipyramidal class. $a : c = 1 : 1.567$. Very small, acute pyramidal crystals consisting usually of the modified bipyramid with m equal to 2. Also short columnar, and arranged in spherical groups.

Hardness 3. Specific gravity 7.8 to 8.2. Conchoidal fracture. Color gray, brown, yellow, green, or red. Greasy luster. Translucent. Easily fusible. Reacts for lead and tungsten. Occurs with quartz and mica at Zinnwald, Saxony; Coquimbo, Chile; Broken Hill, New South Wales.

Huebnerite, MnWO_4 .

Monoclinic, prismatic class. $a : b : c = 0.8362 : 1 : 0.8668$, $\beta = 90^\circ 52'$. Generally in long fibrous, bladed, or stalky crystals without good terminations. Brownish red, brownish black, pale yellow, or nearly black in color, in transmitted light ruby red to yellow. Streak yellowish brown to greenish gray. Vitreous to resinous luster. Hardness 4.5 to 5.5. Specific gravity 6.7 to 7.3. Perfect clinopinacoidal cleavage. Often translucent. Occurs with quartz in Ouray and San Juan Counties, Colorado; Dragoon, Arizona; Black Hills, S. Dakota; Mammoth district, Nevada; Inverness Co., Nova Scotia; Adverville, Pyrenees Mountains; Peru.

Hübnerite is an important ore of tungsten.

WOLFRAMITE, Wolfram, $(\text{Fe}, \text{Mn})\text{WO}_4$.

Monoclinic, prismatic class. $a : b : c = 0.8300 : 1 : 0.8678$, $\beta = 90^\circ 38'$. Formerly considered orthorhombic. Crystals are generally large, thick tabular (Fig. 81), or short columnar; more rarely fibrous. The common forms are the unit prism m , orthopinacoid a , modified orthodomes t and y with the coefficient m equal to $\frac{1}{2}$, and the unit clinodome f . Vertical striations are characteristic of the faces in the prism zone. Contact twins with the twinning plane parallel to the orthopinacoid are rather common. Occurs also in bladed, curved lamellar, columnar, or granular masses.

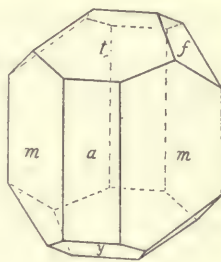


FIG. 81.

Perfect orthopinacoidal cleavage. Uneven fracture. Brittle. Hardness 5 to 5.5. Specific gravity 7.1 to 7.5. Greasy submetallic luster. Color dark gray, reddish brown, brownish black, and iron black. Streak varies from dark red brown for manganiferous varieties to black for those containing much iron. Opaque. Sometimes slightly magnetic.

$(\text{Fe}, \text{Mn})\text{WO}_4$. An isomorphous mixture of FeWO_4 and MnWO_4 in varying proportions. The percentage of FeO varies from 2 to 19%, MnO from 6 to 22%, while WO_3 averages about 75%. May contain small amounts of the oxides of calcium, magnesium, columbium, and tantalum. Fuses with difficulty to a magnetic globule. Fused with sodium carbonate and potassium nitrate on charcoal or platinum foil the mass turns green. Treated with sulphuric or hydrochloric acids and metallic tin the solution assumes a deep blue color. Occurs at times as a pseudomorph after scheelite.

Usually found with *tin ore deposits*, of which it is a typical associate, see page 81. Sometimes with other ore deposits, such as galena, etc. Some localities are Cornwall, England; various places in Saxony; Nertschinsk, Siberia; Bolivia; New South Wales; Felsöbánya, Hungary; Monroe and Trumbull, Conn.; Black Hills, S. Dakota; Mecklenburg Co., N. C.; Mine La Motte, Mo.; Okanogan and Stevens Counties, Wash.; in considerable quantities in Boulder Co., Colorado. In 1907 the United States produced 1,640 tons valued at \$890,048. The supply was obtained chiefly from Colorado.

Wolframite is the chief source of tungsten and its compounds. Tungsten is used in the manufacture of "high-speed" steels and in electric incandescent lamps; sodium tungstate as a mordant and to render fabric non-inflammable; tungstic oxide to color glass; and calcium tungstate, on account of its phosphorescent properties, in X-ray apparatus.

FERBERITE, FeWO_4 . Monoclinic, prismatic class. Artificial crystals have the following elements of crystallization, $a : b : c = 0.8229 : 1 : 0.8463$, $\beta = 90^\circ 20'$. Occurs in compact, granular aggregates, resembling wolframite. Black in color. Streak brownish black to black. Vitreous luster. Sierra Almagrera, Spain; South Dakota.

Uraninite, Pitchblende.

Cubic, hexoctahedral class. Crystals generally show the octahedron and rhombic dodecahedron. Crystals are rare, more commonly in compact, botryoidal, reniform, columnar, and curved lamellar masses. Often apparently amorphous.

Conchoidal to uneven fracture. Brittle. Hardness 3 to 6. Specific gravity 4.8 to 9.7, crystals 9 to 9.7. Pitchy or greasy luster on fresh fracture surfaces, otherwise dull luster. Pitch black, brownish, greenish, or gray in color. Non-magnetic. Streak dark green, brown to gray black.

Composition is uncertain. Is considered an uranate of uranyl and lead with varying percentages of the rare earths—thorium, cerium, yttrium, lanthanum, erbium, etc.,—and the gases nitrogen, argon, and helium. Very small amounts of radium, polonium, and actinium are present in some varieties. As the result of alteration and admixture varying percentages of water, silica, ferrous oxide, calcium oxide, bismuth, arsenic, and sulphur are sometimes noted. Rarely do the oxides of uranium exceed 80 to 85%. *Cleveite* is a variety from Garta, near Arendal, Norway, and aside from thorium also contains argon and helium. *Nivenite* is characterized by about 10% of the earths of the yttrium group. It occurs in Llano Co., Texas. *Bröggerite* is a variety from the Island of Moss near Christiania, containing considerable thorium.

Uraninite is infusible. Easily soluble in warm nitric or sulphuric acids, the solution yields a sulphur yellow precipitate upon the addition of ammonium hydroxide. In the oxidizing flame it imparts a yellow green color to the salt of phosphorus bead. The color turns green in the reducing flame. With soda gives a lead coating on charcoal.

Uraninite occurs in two ways. (1) As a *primary constituent* of pegmatites and granites. Here uraninite is associated with orthite, thorite, fergusonite, etc., and is found in the Arendal and Moss districts, Norway; Oeregrund, Sweden; Branchville, Conn.; Mitchell Co., N. C.; Marietta, S. C.; Llano Co., Texas; and the Black Hills, S. Dakota. (2) *With metaliferous ore deposits* of lead, silver, and bismuth minerals. Thus, at Joachimsthal and Příbram, Bohemia; Johanngeorgenstadt, Schneeberg, etc., Saxony; Rezbánya, Hungary; Cornwall, England; in considerable quantities associated with auriferous sulphide minerals in the Black Hawk, Kirk, and Wood mines, Gilpin Co., Colorado. The variety from Joachimsthal is very strongly radio-active.

Uraninite is the principal source of uranium and its compounds. Uranium is used in the manufacture of special grades of steel, the compounds for coloring glass and in the preparation of pigments for porcelain painting. As indicated above, uraninite is also important as the source of some of the rare elements, such as radium, polonium, actinium, argon, and helium. Uraninite containing about 50% of uranium oxide is worth about \$1,500.00 per ton.

3. BASIC SULPHATES AND CHROMATES

ALUNITE GROUP

This group embraces the basic sulphates of aluminium, sodium, potassium, iron, and lead. These minerals crystallize in the hexagonal system.

$a : c$

Alunite, $K_2(Al_2OH)_6(SO_4)_4$. Ditrigonal Scalenohedral Class I : 1.2520

JAROSITE, $K_2(Fe_2OH)_6(SO_4)_4$.

Ditrigonal Scalenohedral Class I : 1.2492

NATROJAROSITE, $Na_2(Fe_2OH)_6(SO_4)_4$.

Ditrigonal Scalenohedral Class I : 1.1040

PLUMBOJAROSITE, $Pb(Fe_2OH)_6(SO_4)_4$.

Ditrigonal Scalenohedral Class I : 1.2160

Natrojarosite and plumbojarosite are very rare minerals.

Alunite, Alum Stone, $K_2(Al_2OH)_6(SO_4)_4$.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.2520$. Small, rhombohedral crystals resembling cubes. Rhombohedral angle is $90^\circ 50'$. Crystal faces are often curved. Tabular crystals are rare. Also in fibrous, granular, and earthy masses.

Perfect basal cleavage. Conchoidal, splintery, or earthy fracture. Hardness 3.5 to 4, sometimes harder due to admixtures of quartz, feldspar, etc. Specific gravity 2.58 to 2.8. Colorless, white, yellowish, or reddish. White streak. Pearly luster on cleavage surfaces, otherwise vitreous. Transparent to subtranslucent.

$K_2(Al_2OH)_6(SO_4)_4$ sometimes written $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 2Al_2(OH)_6$. Water is liberated only at a comparatively high temperature. In *natroalunite* some of the potassium is replaced by sodium. Decrepitates and is infusible. Heated with cobalt nitrate it turns blue. Reacts for sulphur when fused on charcoal with soda. Soluble in potassium hydroxide and hot sulphuric acid. Insoluble in hydrochloric acid and water.

Alunite occurs in irregular deposits and veins in altered feldspathic rocks, such as rhyolites, dacites, trachytes, and andesites. The common associates of alunite are kaolin, pyrite, opal, and quartz. It occurs at Tolfa, near Rome, Italy; Santorin and elsewhere in the Grecian Archipelago; near Muszay, Hungary; Mount Dore, France; Queretaro, Mexico. In the United States alunite is found in the Rosita Hills, Calico Peak near Rico, National mine near Silverton, and Cripple Creek, Colorado; Tres Cerritos, Mariposa Co., California; Ryerson mine near Morenci, Arizona; and in large quantities associated with gold in the Goldfield district, Nevada. It was formerly thought that alunite is the result of the action of sulphurous vapors on feldspathic rocks. However, Ransome has shown very recently that the alunite of the Goldfield district, Nevada, is due to the action of percolating water charged with sulphuric acid, resulting from the oxidation of pyrite, upon feldspathic rocks, especially trachytes.

By roasting, lixiviating, and evaporating 60 to 80% of alum may be obtained. Some of the Hungarian varieties are so hard and tough as to be suitable for millstones.

JAROSITE, $K_2(Fe.2OH)_6(SO_4)_4$.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.2492$. Usually in small, tabular crystals consisting of the unit rhombohedron and the basal pinacoid. The rhombohedral angle is $90^\circ 45'$. Crystals occur often in druses or crusts. Also in fibrous, granular, and nodular masses.

Distinct basal cleavage. Brittle. Hardness 2.5 to 4. Specific gravity 3.15 to 3.26. Vitreous to subadamantine luster, also dull. Ocher yellow, yellowish brown, or clove brown in color. Shiny yellow streak. Translucent to opaque.

The formula may be written $K_2SO_4.Fe_2(SO_4)_3.2Fe_2(OH)_6$. Occurs at Barranco Jaroso in Sierra Almagrera, Spain; Schwarzenberg, Saxony; Beresowsk, Ural Mts.; Vulture mine, Arizona; Tintic district, Utah; Chaffee Co., Colorado.

NATROJAROSITE contains sodium replacing some of the potassium. It has been found in Nevada.

PLUMBOJAROSITE is a variety containing lead replacing potassium. It has been noted on Cook's Peak, Colorado.

BROCHANTITE GROUP

This group embraces basic sulphates of copper and lead.

LINARITE, $(Pb,Cu)SO_4.(Pb,Cu)(OH)_2$.	Monoclinic, Prismatic Class
STELZNERITE, $CuSO_4.2Cu(OH)_2$.	Orthorhombic, ?
Brochantite, $CuSO_4.3Cu(OH)_2$.	Orthorhombic, Bipyramidal Class

Each mineral differs in composition from the preceding by $Cu(OH)_2$.

LINARITE, $(Pb,Cu)SO_4.(Pb,Cu)(OH)_2$. Monoclinic, prismatic class. $a : b : c = 1.7186 : 1 : 0.8272$, $\beta = 102^\circ 33'$. Small, highly modified crystals with perfect orthopinacoidal cleavage. Conchoidal fracture. Hardness 2.5 to 3. Specific gravity 5.3 to 5.45. Azure blue in color. Light blue streak. Adamantine luster. Transparent to translucent. Occurs at Linares, Spain; Leadhills, Scotland; Beresowsk, Ural Mts.; Inyo Co., California. Rare.

STELZNERITE, $CuSO_4.2Cu(OH)_2$. Orthorhombic system, class undetermined. $a : b : c = 0.5037 : 1 : 0.7059$. Small, prismatic crystals. Green in color. Vitreous luster. Resembles brochantite. Occurs at Remolinos, Chile.

Brochantite, $CuSO_4.3Cu(OH)_2$.

Orthorhombic, bipyramidal class. $a : b : c = 0.7803 : 1 : 0.4838$. Small, short prismatic crystals with vertical striations. Also reniform with fibrous structure and as drusy crusts.

Perfect brachypinacoidal cleavage. Hardness 3.5 to 4. Specific gravity 3.78 to 3.9. Emerald to blackish green in color. Vitreous to pearly luster. Light green streak. Transparent to translucent.

$\text{CuSO}_4 \cdot 3\text{Cu}(\text{OH})_2$. Loses water at 300°C . leaving a residue consisting of a mixture of copper sulphate and oxide. Fuses on charcoal and yields a globule of metallic copper. Reacts for sulphur with soda on charcoal.

Occurs with other copper minerals—malachite, azurite, and cuprite—in the zone of oxidation of copper ore deposits. Thus at Rezbánya, Hungary; Nijni-Tagilak, Ural Mountains; Chile; Copper districts of Arizona; Sonora, Mexico; Monarch mine, Chaffee Co., Colorado.

4. ANHYDROUS SULPHATES WITH HALOIDS AND CARBONATES

Here may be placed several minerals which are combinations of sulphates with chlorides or fluorides, and carbonates. No definite chemical or crystallographic relationships exist between them.

SULPHOHALITE, $3\text{Na}_2\text{SO}_4 \cdot \text{NaCl} \cdot \text{NaF}$.

Cubic, probably hextetrahedral class. Occurs as small, brilliant rhombic dodecahedrons. Pale greenish yellow in color. Transparent. Slowly soluble in water. Found on hanksite at Borax Lake, San Bernardino Co., California.

HANKSITE, $9\text{Na}_2\text{SO}_4 \cdot 2\text{Na}_2\text{CO}_3 \cdot \text{KCl}$.

Hexagonal. $a : c = 1 : 1.0056$. Short prismatic or tabular crystals, sometimes resembling quartz. Colorless to yellow. Transparent to translucent. Easily soluble in water. Occurs with halite, glauberite, thenardite, or sulphohalite at Borax Lake, San Bernardino Co., and Death Valley, Inyo Co., California.

Leadhillite, $\text{PbSO}_4 \cdot 2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$.

Monoclinic, prismatic class. $a : b : c = 1.7515 : 1 : 2.2261$, $\beta = 90^\circ 28'$. Tabular crystals with an apparently hexagonal outline. Crystals usually consist of the unit prism, and the basal and orthopinacoids. The angle between the orthopinacoid and unit prism is $120^\circ 27'$. Twins and trillings resembling those of aragonite. The twinning plane is parallel to the unit prism. Also in compact lamellar masses.

Very perfect basal cleavage. Hardness 2.5. Specific gravity 6.26 to 6.55. Rather sectile. Pearly luster on the basal pinacoid, elsewhere resinous adamantine. Generally yellow, gray, greenish, or brown in color, rarely colorless. White streak. Transparent to translucent.

$\text{PbSO}_4 \cdot 2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$. Fuses easily with intumescence, turns yellow, and when cold is white. Is easily reduced on charcoal to metallic lead. With soda on charcoal reacts for sulphur. Yields water in closed tube.

Soluble in nitric acid with effervescence leaving a white residue of lead sulphate. Occurs as a pseudomorph after galena and calcite.

Is usually associated with lead minerals. Found sparingly at Leadhills, Scotland; Red Gill, Cumberland; Matlock, Derbyshire; Iglesias, Sardinia; also in Missouri, Montana, and Arizona.

5. HYDRATED SULPHATES

Mirabilite, Glauber Salt, Exanthalite, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 1.1161 : 1 : 1.2383$, $\beta = 107^\circ 45'$. Crystals resemble those of pyroxene in form and angle. Usually as a mealy efflorescence or in crusts, sometimes with a fibrous structure.

Perfect orthopinacoidal cleavage. Hardness 1.5 to 2. Specific gravity 1.4 to 1.5. Vitreous luster. Colorless and transparent. On exposure loses water, turns white, and falls to powder. Cooling, salty, bitter taste.

$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$. When exposed to air loses 8 molecules of water and becomes covered with a white crust. Easily soluble in water. Imparts a yellow color to the flame. Dissolves in its water of crystallization.

Occurs as a secondary mineral in the halite deposits at Hallstatt, Hungary, and Berchtesgaden, Bavaria. Is often deposited from hot springs and salt lakes, thus at Karlsbad, Bohemia; Great Salt Lake, Utah; Bay of Kara, Caspian Sea. Near Laramie, Wyoming, it occurs in considerable quantities mixed with mud.



FIG. 82.

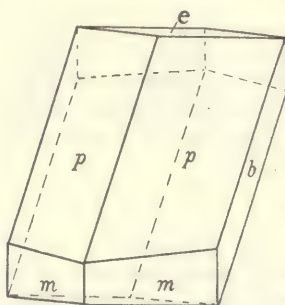


FIG. 83.

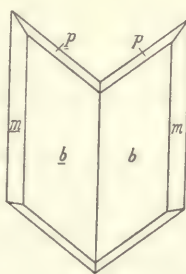


FIG. 84.

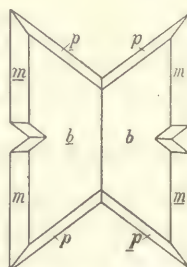


FIG. 85.

GYPSUM, Selenite, Satin Spar, Alabaster, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.6896 : 1 : 0.4133$, $\beta = 98^\circ 58'$. Crystals are usually rather simple and either tabular (Figure 82) or prismatic (Figure 83) in habit. The common forms are the unit prism m , clinopinacoid b , negative unit hemipyramid p , and the modified positive hemi-orthodome e with the coefficient m equal to $1/3$. The prism angle is

$111^{\circ}30'$. Often lenticular due to the rounding of the faces of p and e . Twins according to two laws: (1) The orthopinacoid, which is rarely observed on gypsum, is the twinning plane. Contact (Figure 84) and penetration (Figure 85) twins according to this law are commonly noted. The contact twins (Figure 84) are often termed *swallow-tail twins*. (2) The negative unit orthodome is the twinning plane. Twins according to this law are common at Montmartre near Paris and are sometimes called *Parisian twins*. Crystals are sometimes bent and twisted, and arranged in groups. Also massive, coarse and fine granular, fibrous, foliated, earthy, and as sand.

Three easily obtainable cleavages are to be noted: (1) Highly perfect, parallel to the clinopinacoid; (2) fibrous, parallel to the positive unit hemi-pyramid; and (3) conchoidal, parallel to the orthopinacoid. Hardness 1.5 to 2. Specific gravity 2.2 to 2.4. Pearly luster on the clinopinacoid, elsewhere vitreous; massive varieties are often dull earthy. Transparent to opaque. Colorless, white, gray, yellow, brown, reddish, or black. White streak.

$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. Often mixed with organic matter or clay. Yields water when heated in a closed tube, becomes white and opaque. Imparts a yellow red color to the flame and fuses to an alkaline globule. Soluble in 380 to 460 parts of water, with difficulty in acids, and completely in hot potassium hydroxide. Treated with a cold solution of sodium carbonate it yields calcite, with a hot solution aragonite. It is converted to anhydrite in a hot solution of halite.

There are five varieties of gypsum.

(1) *Selenite*. This variety includes crystals and cleavable masses. Usually colorless and transparent.

(2) *Satin Spar*. Fine fibrous variety with silky luster. Compare page 113.

(3) *Alabaster*. A massive, fine-grained variety. Sometimes used for statuary purposes.

(4) *Rock Gypsum*. A compact, scaly or granular variety. Often very impure. Is commonly ground and used as a fertilizer under the name of *land plaster*.

(5) *Gypsite*. An impure, earthy or sandy variety occurring abundantly in Kansas, Arizona, New Mexico, Oklahoma, and other western states.

Gypsum occurs in large deposits in limestones and shales commonly associated with halite, celestite, sulphur, aragonite, and anhydrite. It also occurs in smaller quantities with metalliferous ore deposits, especially those containing sulphide minerals. Gypsum may be formed in several ways.

(1) *Deposition from solution*. The extensive deposits of rock gypsum, which are of great commercial importance, have been formed by the

gradual evaporation of water in lakes or shallow arms of the sea. At first the calcium sulphate in solution will be deposited as gypsum but, as the brine becomes more concentrated and the percentage of sodium chloride greatly increased, it is precipitated as anhydrite, see page 101. In many cases the evaporation was sufficient to cause only gypsum to be deposited when an influx of water, containing much earthy matter in suspension, greatly diluted the solution. As a result of such disturbances during evaporation, and of the subsequent deposition of the suspended matter, layers of gypsum and shale commonly alternate. Deposits of gypsum formed in this way are very extensive and occur in New York, Michigan, Kansas, Iowa, Texas, Oklahoma, Wyoming, Oregon, Utah, California, New Mexico, South Dakota and Montana. Some of the best known and most extensively worked localities are in Central and Western New York, Alabaster and Grand Rapids, Michigan; Fort Dodge, Iowa; Blue Rapids, Gypsum City, and Medicine Lodge, Kansas; etc. Large deposits occur also at Hillsboro, Albert Co., New Brunswick; and in Nova Scotia. Excellent, transparent crystals are found at Ellsworth and Canfield in Trumbull Co., also in Mahoning Co., Ohio; very large crystals in Wayne Co., Utah.

Gypsite is thought to have been deposited from springs. These spring waters carry much calcium sulphate in solution, having derived the same by leaching deposits of gypsum of the character just described. Some of the deposits in Oklahoma may be the result of erosion and concentration by water of disintegrated rock gypsum.

(2) *Hydration of anhydrite.* Gypsum may also be formed by the hydration of anhydrite, see page 133. This change causes the associated rocks to be locally disturbed. Gypsum formed in this way occurs in Central New York, Northern Ohio, and elsewhere.

(3) *Fumarole action.* Sulphurous vapors react with limestone or the calcium oxide of decomposing lavas and form gypsum. Gypsum formed in this way occurs only in volcanic regions.

(4) *Decomposition of sulphide minerals.* Much of the gypsum found with metalliferous ore deposits has been formed in this way. The oxidation of the sulphides yields sulphuric acid which reacts with the limestones of the region and forms gypsum. Gypsum formed by the third and fourth methods is of rather limited occurrence.

Ground rock gypsum is used extensively as a fertilizer and is commonly called *land plaster*. It is also used as a disinfectant, flux in glass and porcelain manufacture, in cement, and to weight fertilizers. Alabaster is used for statuary and decorative purposes. Satin spar and a small amount of selenite are used in cheap jewelry and microscopy, respectively.

Ground gypsum, or *terra alba*, is used as an adulterant of food, medicine, and paint.

Gypsum, when calcined so as to drive off $1\frac{1}{2}$ molecules of water, is called *plaster of paris*. Calcined gypsum has the property of "setting," or becoming hard, after being mixed with water. It is used in large quantities in patent wall plasters, stucco, white wash, dentistry, crayons, moulds, casts, etc., etc.

In 1908 the production of gypsum in the United States amounted to 1,721,829 tons, valued at \$4,138,560. Michigan and New York are the largest producers. The price of rock gypsum varies between 45 cents to \$3.50 per ton, ground gypsum is worth about \$2.00 per ton, while plaster of paris is valued at about \$3.50 per ton.

Kieserite, $\text{MgSO}_4 \cdot \text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.9046 : 1 : 1.7739$, $\beta = 91^\circ 7'$. Sometimes in large, pyramidal crystals, but more commonly in coarse or fine granular aggregates or masses. Colorless, white, gray, or yellow. Transparent to translucent. Hardness 3. Specific gravity 2.5 to 2.57.

$\text{MgSO}_4 \cdot \text{H}_2\text{O}$. Absorbs moisture and becomes covered with a white coating of epsomite, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$. Heated in a closed tube yields water at 200°C . Powdered kieserite, when mixed with water, hardens like plaster of paris. Slowly soluble in water.

Occurs in large quantities in the salt deposits in the Stassfurt district, Germany, see page 101; also at Kalusz, Galicia; Hallstatt, Austria; and in the Salt Range, British India.

Kieserite is a source of potassium compounds.

EPSOMITE—MELANTERITE GROUPS

These groups include the normal sulphates of magnesium, zinc, nickel, iron, cobalt, manganese, and copper which crystallize with seven molecules of water. There are two—orthorhombic and monoclinic—series.

EPSOMITE GROUP

(ORTHORHOMBIC SYSTEM)

		a	b	c
Epsomite, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.	Bisphenoidal Class	0.9901	1	0.5709
GOSLARITE, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$.	Bisphenoidal Class	0.9804	1	0.5631
MORENOSITE, $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$.	Bisphenoidal Class	0.9815	1	0.5656

MELANTERITE GROUP

(MONOCLINIC SYSTEM)

	a	b	c	β
Melanterite , $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. Prismatic Class	1.1828	1	1.5427	$104^\circ 16'$
MALLARDITE , $\text{MnSO}_4 \cdot 7\text{H}_2\text{O}$. Prismatic Class			?	
LUCKITE , $(\text{Fe}, \text{Mn})\text{SO}_4 \cdot 7\text{H}_2\text{O}$. Prismatic Class			?	
PISANITE , $(\text{Fe}, \text{Cu})\text{SO}_4 \cdot 7\text{H}_2\text{O}$.				

	Prismatic Class	1.1609	1	1.5110	$105^\circ 22'$
CUPROMAGNESITE , $(\text{Cu}, \text{Mg})\text{SO}_4 \cdot 7\text{H}_2\text{O}$. Prismatic Class				?	
BIEBERITE , $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$. Prismatic Class	1.1835	1	1.4973	$104^\circ 55'$	

The elements of crystallization given for the members of the melanterite group are for artificial crystals.

Epsomite, Epsom Salt, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.

Orthorhombic, bisphenoidal class. $a : b : c = 0.9901 : 1 : 0.5709$. Crystals show a combination of the unit prism m , and the right and left unit bisphenoids z and l , Figure 86. The prism angle is $90^\circ 38'$, crystals are, hence, nearly quadratic in cross-section. In nature usually in granular, fibrous, or earthy aggregates; as an efflorescence, crust, and stalactitic.

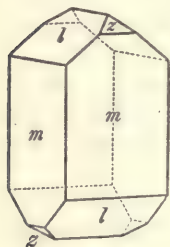


FIG. 86.

Perfect brachypinacoidal cleavage. Hardness 2 to 2.5. Specific gravity 1.7 to 1.8. Colorless or white. Transparent to translucent. Streak white. Bitter, saline taste.

$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$. Soluble in water. Yields water when heated in a closed tube. Heated with cobalt nitrate solution it turns pink. Is non-hygroscopic.

Epsomite is a common constituent of ocean and spring water. Thus, it occurs in the spring water at Epsom, England; Sedlitz, Saidschütz, and Püllna, Bohemia; Ofen, Hungary. As an alteration product of kieserite it occurs in the Stassfurt Salt district, Germany. In some cases may be formed by the action of sulphuric acid on serpentine, talc, magnesite, or other magnesian rocks. At Montmartre, near Paris, epsomite occurs with gypsum. It is also found in the limestone caves of Kentucky, Tennessee, and Indiana.

Epsomite is used in the manufacture of sodium and potassium compounds, in medicine, as a fertilizer in place of gypsum, and as a coating for cotton cloth.

GOSLARITE, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$. Orthorhombic, bisphenoidal class. $a : b : c = 0.9804 : 1 : 0.5631$. Long, columnar crystals. Prism angle is $91^\circ 7'$. Usually as acicular crystals or earthy aggregates, crusts, or stalactitic. Perfect brachypinacoidal cleavage. Hardness 2 to 2.5. Specific gravity 2 to 2.1. Colorless, white, yellowish, or gray. Astringent taste. Is an alteration product of zinc minerals, especially sphalerite. Occurs with melanterite and copiapite. Some localities are Rammelsberg near

Goslar in the Hartz Mountains; Schemnitz, Hungary; Falun, Sweden; Gagnon, Montana.

Ferrogoslarite is a variety containing about 5% of ferrous sulphate. It occurs at Webb City, Jasper Co., Missouri.

MORENOSITE, $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$. Orthorhombic, bisphenoidal class. $a : b : c = 0.9815 : 1 : 0.5656$. Generally as emerald green or greenish white acicular crystals or fibrous efflorescence. It is an alteration product of nickel minerals. Occurs at Riechelsdorf, Hesse; Cape Ortegal, Spain; Wallace Mine on Lake Huron.

Melanterite, Copperas, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 1.1828 : 1 : 1.5427$, $\beta = 104^\circ 16'$. These values are for artificial crystals. Natural crystals are rare. Usually as capillary, fibrous, or stalactitic crusts or efflorescences.

Crystals possess basal and prismatic cleavages. Conchoidal fracture. Hardness 2. Specific gravity 1.8 to 1.9. Color, various shades of green. White streak. On exposure loses 6 molecules of water and crumbles to a yellowish green powder. Vitreous to dull luster. Transparent to translucent. Sweet, astringent taste, somewhat metallic.

$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. Sometimes contains small amounts of manganese, magnesium, or zinc. Easily soluble in water. Yields water when heated in a closed tube. Reacts for ferrous iron. *Luckite* is a manganiferous variety from Butterfield Canyon, Utah.

Melanterite is the result of the decomposition of various minerals containing sulphide of iron, especially pyrite, marcasite, pyrrhotite, and chalcopyrite. Some localities are Goslar, Hartz Mountains; Bodenmais, Bavaria; Falun, Sweden; Rio Tinto, Spain; Herrengrund, Hungary; etc. In the United States it is generally found as an efflorescence associated with the sulphides of iron.

Melanterite does not occur abundantly enough in nature to be of commercial importance. The artificial compound is used extensively as a mordant in dyeing, as a disinfectant, and in the manufacture of ink, bluing, and pigments.

MALLARDITE, $\text{MnSO}_4 \cdot 7\text{H}_2\text{O}$, occurs in colorless, fibrous aggregates in the Lucky Boy mine, Butterfield Canyon, Utah. It is easily soluble in water.

PISANITE, $(\text{Fe}, \text{Cu})\text{SO}_4 \cdot 7\text{H}_2\text{O}$. This is a cupriferous melanterite occurring in blue crystalline aggregates in Turkey. *Salvadorite* is a variety similar to pisanite. It occurs in the Salvador mine, Quetena, Chile.

CUPROMAGNESITE, $(\text{Cu}, \text{Mg})\text{SO}_4 \cdot 7\text{H}_2\text{O}$, occurs as green crusts on Mt. Vesuvius in the lava flows of 1872.

BIEBERITE, $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$, occurs as light red coatings, crusts, or stalactites at Bieber, Hesse.

Chalcanthite, Blue Vitriol, Blue-Stone, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

Triclinic, pinacoidal class. $a : b : c = 0.5656 : 1 : 0.5499$, $\alpha = 97^\circ 39'$, $\beta = 106^\circ 49'$, $\gamma = 77^\circ 37'$. Rarely as small, flat crystals. Occurs generally in crusts with reniform, stalactitic, or fibrous structure.

Crystals possess imperfect basal and prismatic cleavages. Conchoidal fracture. Hardness 2.5. Specific gravity 2.1 to 2.3. Brittle. Vitreous luster. Color varies from deep to sky or greenish blue. Translucent. Disagreeable metallic taste.

$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. May contain some iron. Fuses and imparts a green color to the flame. Easily reduced to metallic copper with soda on charcoal. Readily soluble in water yielding a blue solution, especially if ammoniacal.

Chalcanthite is an alteration product of various copper minerals especially chalcopyrite, bornite, etc. Occurs in the mines at Goslar, Hartz Mountains; Herrengrund, Hungary; Falun, Sweden; Rio Tinto, Spain; Chessy, France, and Cornwall, England. It was formerly found in considerable quantities in the Bluestone mine near Reno, Nevada, and at Copiapo, Chile. Occurs also in the mines near Clifton and Jerome, Arizona; Polk Co., Tennessee; in stalactites in the Butte Copper district, Montana. Copper is easily extracted from mine waters containing much chalcanthite by precipitation with scrap iron.

Occurs only rarely in sufficient quantities to be of commercial importance. The artificial compound is used extensively in copper-plating, in batteries, as a mordant, preservative of timber, for spraying plants, etc.

COQUIMBITE, $\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.5645$. Small rhombohedral crystals, either thick tabular or short columnar. A combination of a rhombohedron and the basal pinacoid often simulates the octahedron. Generally in fine granular aggregates. Hardness 2 to 2.5. Specific gravity 2 to 2.1. May be colorless, yellowish, greenish, or blue. Usually contains a little Al_2O_3 . Soluble in cold water. Occurs as a decomposition product in the trachyte of Tierra Amarilla near Copiapo, Province of Atacama, Chile.

ALUMINITE, $\text{Al}_2(\text{OH})_4\text{SO}_4 \cdot 7\text{H}_2\text{O}$.

Exact crystallization is unknown, perhaps orthorhombic. Generally in warty, botryoidal or reniform masses consisting of very small tabular or prismatic crystals. The masses are earthy and friable. Hardness 1. Specific gravity 1.8. White in color. Opaque. Easily soluble in hydrochloric acid, but not in water. Occurs in clay at Halle, Saxony; Kochendorf, Württemberg; Mühlhausen, Bohemia; Sussex Co., England; etc.

Copiapite,, Misy, Yellow Copperas, $\text{Fe}_2(\text{Fe.OH})_2(\text{SO}_4)_5 \cdot 18\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.4791 : 1 : 0.9759$, $\beta = 108^\circ 4'$. Crystals are six-sided and tabular. Usually in granular masses or loosely compact aggregates of crystalline scales.

Crystals have a basal cleavage. Hardness 1.5. Specific gravity 2.1. Pearly luster. Yellow to yellowish green in color. Transparent to translucent. Disagreeable metallic taste.



$\text{Fe}_2(\text{Fe.OH})_2(\text{SO}_4)_5.18\text{H}_2\text{O}$. May contain varying amounts of the oxides of aluminium and magnesium. Easily soluble in dilute acid. Reacts for ferrous iron. Fuses and yields a magnetic globule on charcoal. Gives sulphur reaction with soda.

Is the result of the alteration of sulphide minerals of iron especially marcasite, pyrite, and pyrrhotite. Occurs at Copiapo, Chile; Falun, Sweden, and Wherschau, Bohemia.

The term *misy* is sometimes used for copiapite, but it often includes other closely related sulphates.

BLÖDITE, $\text{Na}_2\text{Mg}(\text{SO}_4)_2.4\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 1.3492 : 1 : 0.6717$, $\beta = 100^\circ 49'$. Sometimes as excellent, highly modified, prismatic crystals. Usually in compact, granular, or fibrous masses. Hardness 2.5 to 3.5. Specific gravity 2.22 to 2.28. Colorless, pale yellow, reddish, or bluish green. Easily soluble in water. On account of impurities often loses water of crystallization on exposure and crumbles. Occurs associated with salt deposits at Stassfurt, Germany; Hallstatt, Austria, (*simonyite*); Salt Range, British India, (*warthite*); Astrakhan, Asia, (*astrakhanite*); Argentine Republic, and Chile.

PICROMERITE, Schönite, $\text{K}_2\text{Mg}(\text{SO}_4)_2.6\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.7438 : 1 : 0.4861$, $\beta = 108^\circ 10'$. Occurs as thin crusts associated with kainite in the salt deposits of the Stassfurt district, Germany; also at Kalusz, Galicia. Color is generally white. Formed also by fumarolic action on Mt. Vesuvius. Picromerite is used as a source of potassium salts.

Polyhalite, $\text{K}_2\text{MgCa}_2(\text{SO}_4)_4.2\text{H}_2\text{O}$.

Distinct crystals are unknown. Crystallization is probably monoclinic. Usually in compact fibrous or lamellar masses. Hardness 3 to 3.5. Specific gravity 2.7 to 2.8. Flesh to brick red in color, sometimes white, yellow, or gray. The red color is probably due to the presence of small amounts of ferric oxide. Translucent. Greasy to pearly luster.

$\text{K}_2\text{SO}_4.\text{MgSO}_4.2\text{CaSO}_4.2\text{H}_2\text{O}$. Partially soluble in water, yielding gypsum. Easily fusible. Is an important mineral in the salt deposits of the Stassfurt district, Germany, see page 101. Occurs also at Ischl, Hallstatt, etc., Austria; Vic, Western Germany; Berehtesgaden, Bavaria, and various places in the Alps.

ALUM GROUP

This group includes minerals which are double salts consisting of the sulphates of aluminium and an alkali metal with 24 molecules of water of crystallization. These minerals occur very sparingly in nature, but some of the artificial compounds are well known and used extensively in the laboratory. The artificial compounds crystallize in the dyakisdodecahedral class of the cubic system, the predominating form being the octahedron. Several of the minerals possess but 22 molecules of water of crystallization and are doubly refractive, being perhaps monoclinic.

KALINITE, Potash Alum,	$K_2Al_2(SO_4)_4 \cdot 24H_2O.$
TSCHERMIGITE, Ammonia Alum,	$(NH_4)_2Al_2(SO_4)_4 \cdot 24H_2O.$
MENDOZITE, Soda Alum,	$Na_2Al_2(SO_4)_4 \cdot 24H_2O.$
BOSJEMANITE, Magnesium Alum,	$MgAl_2(SO_4)_4 \cdot 24H_2O.$
APJOHNITE, Manganese Alum,	$MnAl_2(SO_4)_4 \cdot 24H_2O.$
HALOTRICHITE, Iron Alum,	$FeAl_2(SO_4)_4 \cdot 24H_2O.$

All of the above minerals are secondary formations and very soluble in water. They are of little importance to the mineralogist and hence will not be described.

Kainite, $MgSO_4 \cdot KCl \cdot 3H_2O$.

Monoclinic, prismatic class. $a : b : c = 1.2186 : 1 : 0.5863$, $\beta = 94^\circ 54'$. Crystals are generally tabular in habit, but very rare. Usually in fine grained aggregates and masses.

Crystals possess orthopinacoidal and prismatic cleavages. Hardness 2. Specific gravity 2.5 to 3. Colorless, yellow, gray, or red. Translucent. Does not deliquesce.

$MgSO_4 \cdot KCl \cdot 3H_2O$. Some of the potassium may be replaced by sodium. Easily soluble in water, on evaporating the solution, picromerite, $K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$, crystallizes out.

Occurs in the uppermost zone of the salt deposits in the Stassfurt district, Germany, and at Kalusz, Galicia, see pages 100 and 101. Kainite is a secondary mineral and resulted from the decomposition of carnallite.

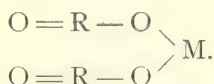
Kainite is important as a fertilizer and as a source of potassium compounds.

VIII. ALUMINATES, FERRITES, BOR- ATES, ETC.

1. ANHYDROUS COMPOUNDS

SPINEL GROUP

This group consists of the metaluminates and ferrites of magnesium, manganese, iron, zinc, chromium, and beryllium which can be referred to the general formula



In this formula R may be replaced by the trivalent elements aluminium, iron, or chromium, and M by the bivalent metals named above. The group is generally divided into a cubic and an orthorhombic series. The members of the cubic series all crystallize in the hexoctahedral class, the octahedron being the predominating form. Chrysoberyl, $\text{Be}(\text{AlO}_2)_2$, is the only member of the orthorhombic series.

CUBIC SERIES

SPINEL , $\text{Mg}(\text{AlO}_2)_2$.	Hexoctahedral Class
PLEONASTE, $(\text{Mg}, \text{Fe}) [(\text{Al}, \text{Fe})\text{O}_2]_2$.	Hexoctahedral Class
HERCYNITE, $(\text{Fe}, \text{Mg})(\text{AlO}_2)_2$.	Hexoctahedral Class
PICOTITE, $(\text{Fe}, \text{Mg}) [(\text{Al}, \text{Cr}, \text{Fe})\text{O}_2]_2$.	Hexoctahedral Class
Gahnite , $\text{Zn}[(\text{Al}, \text{Fe})\text{O}_2]_2$.	Hexoctahedral Class
DYSLUITE, $(\text{Zn}, \text{Mn}) [(\text{Al}, \text{Fe})\text{O}_2]_2$.	Hexoctahedral Class
FRANKLINITE , $(\text{Fe}, \text{Mn}, \text{Zn})(\text{FeO}_2)_2$.	Hexoctahedral Class
CHROMITE , $(\text{Fe}, \text{Cr}) [(\text{Cr}, \text{Fe})\text{O}_2]_2$.	Hexoctahedral Class
JACOBSITE, $\text{Mn}[(\text{Fe}, \text{Mn})\text{O}_2]_2$.	Hexoctahedral Class
MAGNESIOFERRITE, $\text{Mg}(\text{FeO}_2)_2$.	Hexoctahedral Class
MAGNETITE , $\text{Fe}(\text{FeO}_2)_2$.	Hexoctahedral Class

ORTHORHOMBIC SERIES

Chrysoberyl , $\text{Be}(\text{AlO}_2)_2$.	Bipyramidal Class	$\begin{array}{ccc} a & : & b : c \\ 0.4707 & : & 1 : 0.5823 \end{array}$
--	-------------------	---

These minerals are all hard, 5.5 to 8.5. Those with metallic luster are the softer, varying from 5.5 to 6.5.

SPINEL, $\text{Mg}(\text{AlO}_2)_2$.

Cubic, hexoctahedral class. Generally octahedral in habit. Usual combinations consist of the octahedron *o* and rhombic dodecahedron *d*, Figure 87, and, more rarely, the tetragonal trisoctahedron *i* with the coefficient *m* equal to 3, Figure 88. Contact twins with a face of the octahedron acting as the twinning plane, the so-called *Spinel law*, are common, Figure 89.

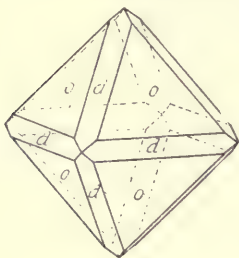


FIG. 87.

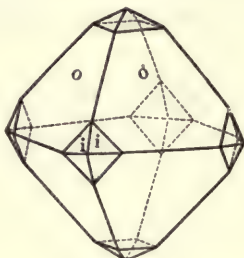


FIG. 88.

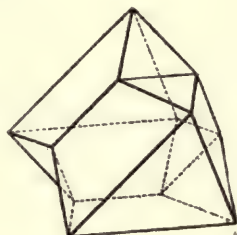


FIG. 89.

Also repeated and polysynthetic twinning according to this law. Occurs usually in disseminated or loose crystals, or rounded grains.

Imperfect octahedral cleavage. Conchoidal fracture. Brittle. Hardness 8. Specific gravity 3.5 to 4.1. Vitreous, splendent, or nearly dull luster. Transparent to translucent. White streak. All colors, but especially various shades of red. $n_{\text{Na}} = 1.72$.

$\text{Mg}(\text{AlO}_2)_2$. May contain small amounts of chromium, iron, and silica. Infusible. Soluble with difficulty in the borax bead. Only slightly acted upon by acids, more readily by potassium bisulphate. Powdered spinel turns blue when heated with cobalt nitrate solution.

Several varieties of spinel may be distinguished, as follows:

- (1) *Balas spinel*. Rose red in color.
- (2) *Ruby spinel*. Deep red variety.
- (3) *Rubicelle*. Yellow or orange red in color.
- (4) *Almandine spinel*. Bluish red in color.
- (5) *Blue spinel*. Light blue in color. Contains about 3.6% of ferrous oxide.
- (6) *Chlorospinel*. Emerald to grass green in color. Contains from 9 to 15% Fe_2O_3 and small amounts of CuO .

Spinel is commonly the result of contact metamorphism, hence, occurs usually in granular limestone, serpentine, or gneiss. The usual associates are chondrodite, corundum, and brucite. Some localities are Aker, Sweden; Amity and Andover districts near the boundary of New York and New



Jersey; various places in St. Lawrence Co., N. Y.; Bolton, Mass.; Franklin Furnace, N. J.; and Macon Co., N. C.

Transparent varieties of good color are used as gems.

PLEONASTE, Ceylonite, Black Spinel, $(\text{Mg,Fe})[(\text{Al,Fe})\text{O}_2]_2$.

Cubic, hexoctahedral class. Crystals are similar to those of spinel proper, but sometimes more highly modified. Hardness 7.5. Specific gravity 3.65 or over. Dark green, brown, or black in color. Usually opaque or nearly so. Uncolored streak. Contains iron replacing both magnesium and aluminium. Pleonaste is a typical contact mineral. It occurs with augite in the Monzoni district, Tyrol; in limestone at Warwick and Amity, N. Y.; Wakefield, Ontario; etc. Also in the placer deposits of Ceylon.

HERCYNITE, Iron Spinel, $(\text{Fe,Mg})(\text{AlO}_2)_2$.

Cubic, hexoctahedral class. Usually as compact, fine granular aggregates, poorly crystallized. Hardness 7.5 to 8. Specific gravity 3.9 to 3.95. Black in color. Gray green streak. Vitreous luster on the conchoidal fracture surface, otherwise dull. Contains iron replacing much of the magnesium. Occurs associated with magnetite and corundum in an hornblende-garnet-gabbro at Ronsberg, Bohemia.

PICOTITE, Chrome Spinel, $(\text{Fe,Mg})[(\text{Al,Cr,Fe})\text{O}_2]_2$.

Cubic, hexoctahedral class. Small, octahedral crystals or irregular grains. Black, yellow or greenish brown in color. Dark brown in transmitted light. Streak pale brown. Translucent to nearly opaque. Hardness 8. Specific gravity 4.08. Picotite is essentially a chrome ceylonite containing over 24% FeO and about 8% Cr_2O_3 . Occurs in olivine rocks such as serpentine, lherzolite, and basalt. Thus at Lherz, Pyrenees Mts., and Scottie Creek, Lillooet district, British Columbia.

Gahnite, Zinc Spinel, Automolite, $\text{Zn}[(\text{Al,Fe})\text{O}_2]_2$.

Cubic, hexoctahedral class. Commonly in octahedral crystals, consisting of the octahedron alone, or in combination with the rhombic dodecahedron. The hexahedron is sometimes observed. Twins according to the spinel law. Also in granular aggregates.

Indistinct octahedral cleavage. Conchoidal fracture. Brittle. Hardness 7.5 to 8. Specific gravity is usually 4.33 to 4.35, may, however, vary from 4.0 to 4.9. Gray streak. Various shades of green, brown, or black in color. Greasy vitreous luster. Translucent to opaque.

$\text{Zn}[(\text{Al,Fe})\text{O}_2]_2$. Some of the zinc is usually replaced by iron, manganese, or magnesium. Infusible. Gives zinc coating on charcoal. Not attacked by acids or alkalis.

Occurs in talc schist at Falun, Sweden; with sulphides of arsenic at Querbach, Schlesia; in granular limestone at Franklin Furnace, N. J.; in granite at Haddam, Conn.; Rowe, Mass.; Delaware Co., Pa.; Mitchell Co., N. C.; Chaffee Co., Colo.; also in the Brazilian diamonds placers of Minas Geraes.

DYSLUITE, $(\text{Zn,Mn})[(\text{Al,Fe})\text{O}_2]_2$. This is a brown, manganiferous gahnite from Sterling Hill, N. J. Specific gravity 4 to 4.6.

FRANKLINITE, $(\text{Fe,Mn,Zn})(\text{FeO}_2)_2$.

Cubic, hexoctahedral class. Crystals are usually octahedral in habit. Common forms are the octahedron and rhombic dodecahedron, Figure 87, page 156. The edges are often rounded. Occurs also in compact, granular masses, and rounded grains.

Imperfect octahedral cleavage. Conchoidal fracture. Hardness 5.5 to 6.5. Specific gravity 5 to 5.22. Metallic or dull luster. Iron black in color. Brown, reddish brown, or black streak. Slightly magnetic.

$(\text{Fe,Mn,Zn})(\text{FeO}_2)_2$. Composition varies greatly, ZnO from 17 to 25%, MnO 10 to 12%, and Fe_2O_3 about 60%. Infusible. When heated becomes more strongly magnetic. With soda on charcoal yields a bluish green color characteristic of manganese and a white coating of zinc oxide. Reacts for manganese with borax bead. Soluble in hot hydrochloric acid with an evolution of chlorine.

Franklinite is commonly associated with willemite, zincite, rhodonite, and calcite, and occurs rather extensively at Franklin Furnace and Sterling Hill, Sussex County, N. J. Also found in cubical crystals at Eibach, Nassau.

Franklinite is a source of zinc, which is easily obtained by heating. The residue contains about 12% of manganese and is used for spiegeleisen in steel manufacture.

CHROMITE, Chrome Iron, Chromic Iron Ore, $(\text{Fe,Cr}) [(\text{Cr,Fe})\text{O}_2]_2$.

Cubic, hexoctahedral class. Rarely in octahedral crystals. Usually in compact, fine granular masses, often as disseminated grains.

Indistinct octahedral cleavage. Uneven to conchoidal fracture. Hardness 5.5. Specific gravity 4.3 to 4.6. Pitchy, submetallic to metallic luster. Opaque. Iron to brownish black in color. Dark brown streak. Sometimes slightly magnetic.

$(\text{Fe,Cr}) [(\text{Cr,Fe})\text{O}_2]_2$. May also contain MgO and Al_2O_3 . The composition varies considerably. Infusible, sometimes becomes magnetic. When hot the borax bead gives the iron reaction, when cold the chromium. Heated on charcoal or platinum foil with soda and potassium nitrate, the mass turns chrome yellow. Insoluble in acids, but decomposed by fusion with potassium acid sulphate.

Chromite occurs usually in veins and irregular masses in basic magnesium rocks, especially serpentine. It is doubtless the result of magmatic separation. It occurs at Frankenstein, Silesia; Ural Mountains; Roeros, Norway; Island of Unst; New Zealand; New Caledonia; and in Asiatic Turkey.

In the United States chromite is found in Chester and Delaware Counties, Pa.; Baltimore Co., Md.; San Luis Co., Cal.; and Burnsville, Yancey

Co., N. C. It is often associated with chrome garnet and zaratite. Chromite is also found in platinum placers and the so-called *black sands*.

Chromite is the source of metallic chromium and its compounds, which are used in the manufacture of special grades of steels and the chrome colors. Chromite is also used in the manufacture of refractory bricks. The production of chromite in the United States is very small. Most of the chromite is imported from New Foundland and Australia.

JACOBSITE, $\text{Mn}[(\text{Fe}, \text{Mn})\text{O}_2]_2$.

Cubic, hexoctahedral class. Occurs in octahedral crystals, also in rounded disseminated grains and granular aggregates. Iron black in color. Metallic luster. Hardness 6. Specific gravity 4.75. Reddish black streak. Opaque. Strongly magnetic. Chemically jacobsite might be considered as a manganiferous magnetite. Occurs in granular limestone at Jakobsberg, Wermland, Sweden.

MAGNESIOFERRITE, Magnoferrite, $\text{Mg}(\text{FeO}_2)_2$.

Cubic, hexoctahedral class. Black, octahedral crystals with a dark red streak. Specific gravity 4.65. Strongly magnetic. Occurs with hematite on the lavas of Vesuvius, Aetna, and Stromboli. It is a sublimation product.

MAGNETITE, Magnetic Iron Ore, Lodestone, $\text{Fe}(\text{FeO}_2)_2$.

Cubic, hexoctahedral class. Octahedral and rhombic dodecahedral crystals are very common. Most abundant is the simple octahedron, Figure 90.

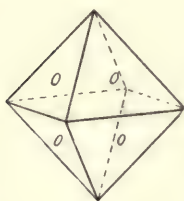


FIG. 90.

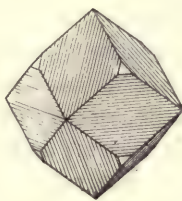


FIG. 91.

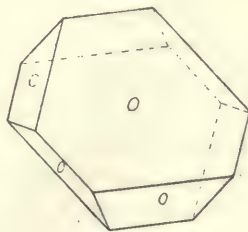


FIG. 92.

The faces of the rhombic dodecahedron are often striated parallel to the long diagonal, Figure 91. Crystals are sometimes highly modified. Over 30 forms have been observed. Contact, Figure 89, page 156, and polysynthetic twins according to the spinel law are rather common. Crystals are often greatly distorted, Figure 92. Occurs also as disseminated grains, lamellar and compact aggregates, coarse and fine grained masses, loose grains or sand, and dendritic, especially in mica.

No distinct cleavage. Excellent octahedral parting, due to polysynthetic twinning, is often observed. Conchoidal to uneven fracture. Brittle. Hardness 5.5 to 6.5. Specific gravity 4.9 to 5.2. Metallic, submetallic, splendent, or dull luster. Iron black in color. Black streak. Opaque, but very thin lamella, especially dentrites in mica, are pale brown to black in transmitted light. Strongly magnetic. A very strongly magnetic variety occurs at Magnet Cove, Arkansas. More or less decomposed varieties sometimes show polarity.

$\text{Fe}(\text{FeO}_2)_2$. Commonly written Fe_3O_4 . Sometimes contains magnesium, nickel, manganese, phosphorus, and titanium. Fuses with difficulty. The powder is easily soluble in hydrochloric acid, and slowly soluble in hydrofluoric acid. Alters to limonite and hematite (martite), page 87. Magnetite occurs as a pseudomorph after pyrite, hematite, and siderite.

Magnetite occurs in several different ways:

(1) *As a primary constituent* of many basic igneous rocks, such as, diabase, gabbro, nepheline syenite, and basalt. It usually occurs as fine, disseminated particles or crystals; also found in lenticular bodies of considerable size, the result of local concentration. Magnetite of this type of occurrence is often titaniferous and may be associated with pyroxene, brown hornblende, olivine, apatite, spinel, garnet, and plagioclase. At present it is of little importance, commercially. Some localities are Taberg, Southern Sweden; Finland; Ural Mountains; Unkel on the Rhine; and various places in New York, New Jersey, Colorado, and Minnesota.

(2) *The result of regional metamorphism.* Here, magnetite is generally found as large deposits, fahlbands, or disseminated, in gneiss, schists, granular limestone, and other metamorphic rocks. The common associates are feldspar, hornblende, quartz, apatite, fluorite, pyrite, and hematite. It is thought that deposits of this character may have been formed (1) by the metamorphism of limonite, hematite, or pyritiferous rocks; (2) by deposition from iron-bearing magmatic waters; and (3) that in some cases they are probably replacement deposits. Magnetite of this type of occurrence is usually non-titaniferous and of great importance, commercially. Large deposits occur in the Arendal district, Norway; Dannemora and Falun, Central Sweden; Southern Russia; Algeria; Brazil; and in the United States at Mineville, N. Y.; Cornwall, Pa.; various places in New Jersey, Virginia, North Carolina, Colorado, Wyoming, Utah, New Mexico, and Michigan. In 1908 the United States produced 1,547,797 long tons* of magnetite of this type of occurrence, obtained principally from New York, New Jersey, and Pennsylvania. This was about 5% of the iron ore mined that year.

* Includes some martite, see page 87.

(3) *The result of contact metamorphism.* Here, magnetite occurs along the contact of plutonic rocks, such as granites, with limestones and schists. This is a rather common method of occurrence. Some deposits of this type may prove to be of commercial importance.

(4) *Black Sands.* Magnetite occurs extensively as a constituent of river, lake, and sea sands, especially in regions of metamorphic and igneous rocks. It is an important constituent of the *black sands*, which occur rather widespread in Alaska, California, Idaho, Montana, Colorado, Oregon, Washington, and New York. It is associated with chromite, ilmenite, garnet, hematite, olivine, monazite, limonite, zircon, quartz, gold, and the platinum minerals. These sands are of importance as a source of platinum, see page 18. At present, experiments are being made to smelt these sands electrolytically with a view to use them as a source of iron.

Magnetite is an important ore of iron.

Chrysoberyl, $\text{Be}(\text{AlO}_2)_2$.

Orthorhombic, bipyramidal class. $a : b : c = 0.4707 : 1 : 0.5823$. Occurs generally in disseminated, tabular crystals. The macropinacoid predominates and is usually vertically striated. Contact twins (Figure 94) and penetration trillings (Figure 95) are very common. Such crystals often show feather-like striations. The twinning plane is the modified brachydome with the coefficient m equal to 3. Penetration trillings (Figure 95) have a pseudo-hexagonal outline and consist, apparently, of an hexagonal bipyramid and basal pinacoid. Occurs also as crystal fragments, and loose or rounded grains.

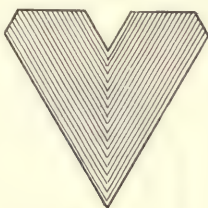


FIG. 94.

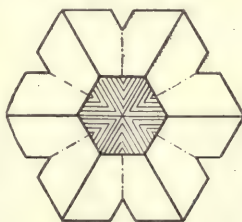


FIG. 95.

Distinct brachypinacoidal cleavage. Conchoidal fracture. Brittle. Hardness 8.5. Specific gravity 3.65 to 3.84. Greasy luster on fracture surfaces, elsewhere vitreous. White streak. Transparent to translucent. Greenish white, greenish yellow, asparagus to emerald green in color; often columbine red in transmitted light. Sometimes pleochroic. Some varieties show a bluish opalescence or chatoyancy.

$\text{Be}(\text{AlO}_2)_2$. May contain some iron. Infusible. Insoluble in acids. The powder turns blue when heated with cobalt nitrate solution.

There are three varieties:

(1) *Ordinary*. Pale green and yellow varieties. When transparent are often used for gem purposes.

(2) *Alexandrite*. Emerald green variety, which is columbine red in transmitted light.

(3) *Cat's Eye or Cymophane*. An opalescent, yellow green variety from Ceylon.

Chrysoberyl is usually found in gneiss, mica schist, or granite. It is commonly associated with beryl, tourmaline, garnet, apatite, or sillimanite. It occurs in the Ural Mountains; Ireland; Haddam, Conn.; Norway and Stoneham, Me.; and Greenfield, N. Y. As rounded pebbles it is found in the gem placers of Ceylon and Brazil.

Alexandrite and cat's eye are often used as gems.

SUSSEXITE, $[(\text{Mn}, \text{Mg})\text{OH}]\text{BO}_2$.

Crystallization unknown. Occurs in asbestos-like fibres in seams and veins in calcite, associated with franklinite, willemite, and zincite in Sussex County, N. J. It is white, pink, or yellowish in color. Translucent. Hardness 3. Specific gravity 3.42. Pearly to silky luster.

Boracite, $\text{Mg}_7\text{Cl}_2\text{B}_{16}\text{O}_{30}$.

Dimorphous, orthorhombic and cubic. At ordinary temperatures boracite is orthorhombic but, owing to twinning, crystals are pseudocubic in development. When heated to 265°C ., crystals become isotropic and, hence, cubic. Tetrahedral, cubical (Figures 96 to 98), and dodecahedral habits are common. The forms commonly observed are the tetrahedron *o*, cube *h*, and rhombic dodecahedron *d*. Crystals are usually disseminated and small, but well developed.

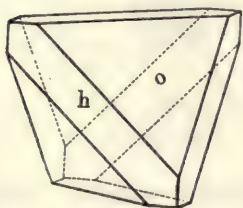


FIG. 96.

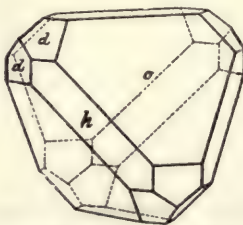


FIG. 97.

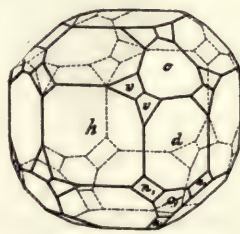


FIG. 98.

No distinct cleavage. Conchoidal fracture. Brittle. Hardness 7. Specific gravity 2.9 to 3. Vitreous luster. Transparent to translucent. White, pale green or blue, gray, and yellow in color. White streak. Strongly pyroelectric.

$\text{Mg}_7\text{Cl}_2\text{B}_{16}\text{O}_{30}$. Sometimes contains calcium, iron, and water. Fuses

with intumescence to a white glass and imparts a greenish color to the flame. Turns pink when heated with cobalt nitrate solution. Slowly soluble in hydrochloric acid.

Boracite occurs disseminated in gypsum, anhydrite, and carnallite in the salt deposits of the Stassfurt district, Germany.

2. HYDRATED COMPOUNDS

BORAX, Tinkal, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 1.0995 : 1 : 0.5630$, $\beta = 106^\circ 35'$. Short, thick prismatic crystals, resembling augite in habit and angles, page ????. The prism angle is 87° . The common forms are the unit prism; basal, ortho-, and clinopinacoids; and the positive unit hemipyramid. Twins are rare, the orthopinacoid acts as twinning plane.

Orthopinacoidal and prismatic cleavages. Rather brittle. Conchoidal fracture. Hardness 2 to 2.5. Specific gravity 1.7 to 1.8. Greasy, vitreous, or earthy luster. Color white, sometimes grayish, bluish, or greenish. Is often covered with a clouded crust. White streak. Alkaline taste. Translucent to opaque.

$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$. Swells up and fuses to a clear, transparent glass, coloring the flame yellow. Heated with a paste of powdered fluorite and potassium bisulphate it colors the flame yellow and then light green. The green flame may be also obtained by igniting a mixture of borax, alcohol, and a few drops of concentrated sulphuric acid. Soluble in 14 parts of cold water.

Occurs on the shores and in the muds of the so-called borax lakes in Thibet, California, Nevada, and Oregon. It is usually associated with halite and soda. Most of the borax used in the United States is prepared from colemanite, $\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 5\text{H}_2\text{O}$, which occurs extensively in San Bernardino, Inyo, Los Angeles, and Ventura Counties, California.

Borax is used in large quantities in the manufacture of soap, enamels, glass, washing powders, ointments, and lotions; also in welding, soldering, assaying, blowpiping, and calico printing. It is an antiseptic and is often employed in the preservation of meat and fish.

Ulexite, Boronatrocalcite, Natronborocalcite, $\text{NaCaB}_5\text{O}_9 \cdot 6\text{H}_2\text{O}$.

Monoclinic, prismatic class. The elements of crystallization are unknown. Found generally in white, rounded, fine fibrous masses. Very soft. Specific gravity 1.65 to 1.8. Silky luster. White streak. Translucent. Tasteless.

$\text{NaCaB}_5\text{O}_9 \cdot 6\text{H}_2\text{O}$. Sometimes it is mixed superficially with halite, gypsum, glauberite, and borax. Easily fusible with intumescence to a clear glass. Imparts a yellow color to the flame. Reacts for boron, see borax, page 163. Soluble with difficulty in hot water. Easily soluble in acids.

Occurs associated with halite, gypsum, glauberite, and borax in arid regions, especially in Nevada, California, Chile, and in Nova Scotia.

It is used to some extent in the manufacture of borax and boracic acid.

PANDERMITE, Priceite, $\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 3\text{H}_2\text{O}$. Monoclinic, prismatic class. Occurs in large quantities in white, chalky or marble-like masses in Panderma, Asiatic Turkey. It is also found in Curry County, Oregon, and San Bernardino County, California.

COLEMANITE, $\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 5\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.7769 : 1 : 0.5416$, $\beta = 110^\circ 17'$. Crystals are usually short prismatic and resemble datolite. Often highly modified. Occurs also in compact, granular masses resembling chalk or porcelain.

Highly perfect clinopinacoidal cleavage. Brittle. Uneven to subconchoidal fracture. Hardness 3.5 to 4.5. Specific gravity 2.42. Vitreous to dull luster. Milky white, white, gray, or yellowish white in color. White streak. Transparent to opaque.

$\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 5\text{H}_2\text{O}$. Imparts a yellowish green color to the flame. Decepsitates, exfoliates, and fuses imperfectly. Easily soluble in hot hydrochloric acid, boracic acid separates on cooling. Insoluble in water. Treated with sodium carbonate it yields borax, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.

Colemanite is the chief source of borax in the United States, see page 163.

SULFOBORITE, $4\text{MgHBO}_3 \cdot 2\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$. Orthorhombic, bipyramidal class. $a : b : c = 0.6168 : 1 : 0.8100$. Small transparent, prismatic crystals. Colorless or slightly reddish. Hardness 4 to 4.5. Specific gravity 2.44. Occurs disseminated in carnallite at Wester-Egeln, Germany.

VIII. PHOSPHATES, ARSENATES, ANTIMONATES, VANADATES, NIOBATES, AND TANTALATES

This class embraces a very large number of minerals of which but comparatively few are of much importance.

1. NORMAL ANHYDROUS COMPOUND

These compounds are salts of the ortho, meta, and pyro acids. Several groups may be differentiated.

TRIPHYLITE GROUP

This group includes the orthophosphates of sodium, lithium, iron, beryllium, and manganese. It consists of four members which crystallize in the orthorhombic system.

	a	b	c
BERYLLONITE, NaBePO_4 .	Bipyramidal Class 0.5724	: 1	: 0.5490
NATROPHILITE, NaMnPO_4 .	Bipyramidal Class 0.4720	: 1	: 0.5550
TRIPHYLITE, Li(Fe,Mn)PO_4 .	Bipyramidal Class 0.4348	: 1	: 0.5266
LITHIOPHILITE, LiMnPO_4 .	Bipyramidal Class 0.4450	: 1	: 0.5550

The elements of crystallization given for natrophilite and lithiophilite are only approximate. Triphylite is the most important member of the group.

BERYLLONITE, NaBePO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.5724 : 1 : 0.549$. Occurs in short prismatic or tabular crystals. Often highly modified. Perfect basal cleavage. Vitreous luster. Colorless, white, or pale yellow. Hardness 5.5 to 6. Specific gravity 2.85. Found in decomposed granite at Stoneham, Me.

NATROPHILITE, NaMnPO_4 , is a very rare mineral. Deep wine yellow in color. Hardness 4.5 to 5. Specific gravity 3.4. Occurs in cleavable masses at Branchville, Conn.

TRIPHYLITE, Li(Fe,Mn)PO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.4348 : 1 : 0.5266$. Crystals are rare. Occurs usually in compact, cleavable masses. Perfect basal cleavage. Un-

even to subconchoidal fracture. Greasy luster. Translucent. Hardness 4 to 5. Specific gravity 3.4 to 3.6. Greenish gray to blue in color. Streak grayish white.

Li(Fe,Mn)PO_4 . Easily fusible. Soluble in hydrochloric acid.

Common associates are spodumene and beryl. Occurs at Rabenstein, Bavaria; Ketyo, Finland; Grafton, N. H.; Norwich, Conn.; and Peru, Me.

LITHIOPHILITE, LiMnPO_4 , differs essentially from triphylite in that it possesses a larger percentage of manganese. Lithiophilite and triphylite grade into one another. Lithiophilite is pale pink to yellow and clove brown in color. It has been found at Branchville, Conn., and Norway, Me.

MONAZITE GROUP

The members of this group are orthophosphates and niobates of the rare earths. They show no definite crystallographic relationship.

Xenotime YPO_4 . Ditetragonal Bipyramidal Class $a : c = 1 : 0.6208$

FERGUSONITE, Y(Nb,Ta)O_4 . Tetragonal Pyramidal Class $1 : 1.4640$

Monazite, $(\text{Ce,La,Di})\text{PO}_4$. Monoclinic Prismatic Class

$a : b : c = 0.9742 : 1 : 0.9227, \beta = 103^\circ 46'$

On account of a very valuable content of thorium dioxide, monazite is, commercially, the most important member of the group.

Xenotime, YPO_4 .

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.6208$. Crystals are either pyramidal or prismatic in habit, resembling zircon, page 79. They occur either disseminated, attached, or as rolled grains in secondary deposits.

Perfect prismatic cleavage. Uneven to splintery fracture. Hardness 4 to 5. Specific gravity 4.45 to 4.56. Greasy to vitreous luster. Various shades of yellow and brown, also flesh red, and pale gray in color. Streak yellowish white, pale brown, or flesh red. Transparent to opaque.

YPO_4 . May contain some erbium and gadolinium. Infusible. Insoluble in hot acids. Colors flame green after being moistened with sulphuric acid.

Occurs in granites and gneisses, often associated with zircon. Thus at Hitterö, Moss, and Arendal, Norway; Ytterby, Sweden; St. Gotthard and Binnenthal, Switzerland; Minas Geraes and Bahia, Brazil; Clarksville, Ga.; Alexander, Burke, Henderson, and Mitchell Counties, N. C.; and Pike's Peak, Colo.

Xenotime is a source of the yttrium group of elements.

FERGUSONITE, Tyrite, Bragite, $Y(Nb,Ta)O_4$.

Tetragonal, pyramidal class. $a : c = 1 : 1.4643$. Crystals are pyramidal or prismatic in habit, and usually poorly developed.

Conchoidal to uneven fracture. Hardness 5.5 to 6. Specific gravity 5.8 to 5.9. Dull luster, on fresh fracture surfaces greasy to submetallic. Brown to pitch black in color. Pale brown streak. Translucent to opaque.

$Y(Nb,Ta)O_4$. May also contain cerium, erbium, yttrium, and uranium. *Sipylite* is a variety containing considerable erbium. Becomes luminous when heated to 500° or 600°C. and evolves a small amount of helium.

Occurs at Cape Farewell, Greenland; Ytterby, Sweden; Arendal, Norway; and in a considerable quantities in Llano County, Texas.

Monazite, Turnerite, $(Ce,La,Di)PO_4$.

Monoclinic, prismatic class. $a : b : c = 0.9742 : 1 : 0.9227$, $\beta = 103^\circ 46'$. Crystals are generally thick tabular or square prismatic in habit. The prism angle is $86^\circ 34'$. Often highly modified. Disseminated or attached. Sometimes twinned, the orthopinacoid acts as the twinning plane. Occurs also in angular masses, but most commonly in rolled grains as monazite sand.

Perfect basal cleavage. Conchoidal fracture. Brittle. Hardness 5 to 5.5. Specific gravity 4.9 to 5.3. Resinous luster. Transparent to opaque. Red, reddish or yellowish brown, and brownish gray in color.

$(Ce,La,Di)PO_4$. May contain from $\frac{1}{2}$ to 19% of thorium dioxide, due doubtless to an admixture of thorite, $ThSiO_4$, page 80. This content of ThO_2 , which is usually about 5% in monazite sands, is of great commercial importance. Infusible. Moistened with sulphuric acid it imparts a greenish color to the flame. Decomposed by hydrochloric acid.

Occurs disseminated as macroscopic or microscopic crystals in granitic rocks. It has been found at Schüttenhofen, Bohemia; Arendal, Norway; Miask, Ural Mountains; Dauphine, France; Binnenthal, Switzerland; and in large masses at Amelia Court House, Va.

The most important occurrence of monazite is as sand. Extensive deposits of such sands occur in the western part of North and South Carolina, and Georgia; in the provinces of Amazonas, Bahia, and Minas Geraes, Brazil; also in the Ural Mountains. The monazite belt of the southern states is over 3,000 square miles in area.

Aside from quartz and magnetite, monazite sands usually contain garnet, zircon, thorite, gold, chromite, and sometimes the diamond.

Monazite is the source of thorium dioxide which is used extensively in the manufacture of incandescent mantles. Brazil, North and South Carolina, and Georgia furnish most of the world's supply. In 1908 the United States produced 422,646 pounds of monazite valued at \$50,718.

YTTRICANTALITE is essentially a pyrotantalite of yttrium, $Y_4(Ta_2O_7)_3$. It usually contains some erbium, calcium, uranium, and niobium pentoxide, Nb_2O_5 . Crystals are orthorhombic and usually poorly developed. Also occurs massive. Black or yellow in color. Submetallic luster. Hardness 5 to 5.5. Specific gravity 5.2 to 5.9. Conchoidal to uneven fracture. Streak grey. Yttricotantalite is a very rare mineral. It has been found at Ytterby and Falun, Sweden.

SAMARSKITE, Yttrilmenite, Uranotantalite.

Orthorhombic, prismatic class. $a : b : c = 0.8803 : 1 : 0.4777$. Crystals are not common. Usually in compact masses or grains.

Conchoidal fracture. Submetallic to greasy luster. Brittle. Hardness 5 to 6. Specific gravity 5.6 to 5.8. Velvet black in color. Dark reddish brown streak. Opaque. Compact masses possess a glassy, amorphous appearance.

Samarskite is a niobate of iron, yttrium, cerium, erbium, and uranium. Tantalum may replace some of the niobium. No definite formula can be assigned to samarskite. Fuses with difficulty. Becomes luminous when heated. Decomposed by concentrated sulphuric acid, yielding a blue solution when boiled with metallic zinc or tin. Gives with salt of phosphorous in both flames an emerald green bead.

Associated with columbite, it occurs in granite at Miask, Ural Mts.; also in Mitchell County, N. C., sometimes in masses weighing as much as 20 pounds.

A source of some of the rarer elements.

COLUMBITE GROUP

The metatantalates and niobates of iron and manganese are dimorphous. One series is tetragonal and the other orthorhombic.

TETRAGONAL SERIES*(Ditetragonal Bipyramidal Class)*

	$a : c$
TAPIOLITE, (Fe,Mn) [(Ta,Nb)O ₃] ₂ .	1 : 0.6522
MOSSITE, (Fe,Mn) [(Nb,Ta)O ₃] ₂ .	1 : 0.6438

ORTHORHOMBIC SERIES*(Orthorhombic Bipyramidal Class)*

	$a : b : c$
Tantalite, (Fe,Mn) [(Ta,Nb)O ₃] ₂ .	0.8304 : 1 : 0.8732
COLUMBITE, (Fe,Mn) [(Nb,Ta)O ₃] ₂ .	0.8285 : 1 : 0.8898

The members of the tetragonal series are of minor importance and will not be described.

Tantalite, (Fe,Mn) [(Ta,Nb)O₃]₂.

Orthorhombic, bipyramidal class. $a : b : c = 0.8304 : 1 : 0.8732$. Habit and development much like columbite. Compact and disseminated.

Conchoidal to uneven fracture. Brachypinacoidal cleavage scarcely perceptible. Hardness 6 to 6.5. Specific gravity 6.3 to 9. Greasy, submetallic luster. Iron black in color. Brownish black streak. Opaque.

(Fe,Mn) [(Ta,Nb)O₃]₂. According to Naumann-Zirkel tantalite is an isomorphous mixture of $m\text{Fe}(\text{TaO}_3)_2$ and $n\text{Fe}(\text{NbO}_3)_2$, where m is

larger than, or at least equal to, n . Infusible. Not attacked by acids. Manganese may replace iron and in *manganotantalite* nearly all the iron has been thus replaced. May also contain tin and titanium.

Occurs in granite at Skogböle and Härkäsaari, Finland; Broddbo and Finbo, Sweden, and Paris, Me.

It is a source of tantalum, which is now of importance in the manufacture of the tantalum incandescent electric lamps.

COLUMBITE, (Fe,Mn) [(Nb,Ta)O₃]₂.

Orthorhombic, bipyramidal class. $a : b : c = 0.8285 : 1 : 0.8898$. Short prismatic or thick tabular crystals, resembling those of wolframite. The three pinacoids, brachyprism ($n=3$), and the macrodome ($m=2$), are the most common forms. Heart-shaped twins with the macrodome, $m=2$, acting as the twinning plane are common. Columbite also occurs massive and disseminated.

Distinct brachypinacoidal cleavage. Conchoidal to uneven fracture. Hardness 6. The specific gravity increases with the amount of Ta₂O₅ present and varies from 5.4 to 6.4. Fracture surfaces show a greasy, submetallic luster. Brown to iron black in color. Streak is brownish, reddish, or black.

(Fe,Mn) [(Nb,Ta)O₃]₂. According to Naumann-Zirkel columbite is a mixture of $m\text{Fe}(\text{NbO}_3)_2$ and $n\text{Fe}(\text{TaO}_3)_2$, where m is larger than, or at least equal to, n . Manganese may replace iron and in *manganocolumbite* it is present in considerable quantities. Columbite and tantalite grade into one another. Infusible. Not attacked by acids. Decomposed by potassium bisulphate. Fused with sodium carbonate and then treated with hydrochloric acid and metallic tin, the solution assumes a light blue color.

Columbite is more abundant than tantalite. It is found with cryolite at Ivigtut, Western Greenland; also at Bodenmais, Bavaria; Tammela, Finland; Miask, Ural Mountains; Woodgina Tin district, Pilbara, Western Australia; Haddam and Branchville, Conn.; Black Hills, S. Dak.; and Pike's Peak, Colo.

Columbite is an important source of niobium and tantalum.

2. BASIC ANHYDROUS COMPOUNDS CONTAINING CHLORINE AND FLUORINE

Some of the most important minerals of this class belong to this section. They are generally salts of the ortho acids and may contain chlorine, fluorine, or an hydroxyl group.

APATITE GROUP

This group includes the orthophosphates, arsenates, and vanadates of calcium and lead. All members of the group crystallize in the hexagonal bipyramidal class of the hexagonal system.

APATITE , $\text{Ca}_5\text{F}(\text{PO}_4)_3$.	Hexagonal Bipyramidal Class	$a : c$ 1 : 0.7346
PYROMORPHITE , $\text{Pb}_5\text{Cl}(\text{PO}_4)_3$.	Hexagonal Bipyramidal Class	1 : 0.7362
Mimetite , $\text{Pb}_5\text{Cl}(\text{AsO}_4)_3$.	Hexagonal Bipyramidal Class	1 : 0.7276
ENDLICHITE , $\text{Pb}_5\text{Cl}[(\text{As}, \text{V})\text{O}_4]_3$.	Hexagonal Bipyramidal Class	1 : 0.7495
Vanadinite , $\text{Pb}_5\text{Cl}(\text{VO}_4)_3$.	Hexagonal Bipyramidal Class	1 : 0.7122

The axial ratio for endllichite is only approximate.

APATITE, $\text{Ca}_5\text{F}(\text{PO}_4)_3$ to $\text{Ca}_5\text{Cl}(\text{PO}_4)_3$.

Hexagonal system, hexagonal bipyramidal class. The axial ratio, $a : c$, varies from 1 : 0.7313 to 1 : 0.7346. Crystals are well developed and often very large. Prismatic (Figures 99 and 100) and thick tabular (Figure 101) crystals are common. The latter are often highly modified. Some of the common forms are the unit prism m and bipyramid x of the first order, the basal pinacoid c , the bipyramid of the second order s ($2a : 2a : a : 2c$), and the bipyramid of the third order u ($3/2a : 3a : a : 3c$). The symmetry of the hexagonal bipyramidal class is readily shown by etch figures. Crystals are often vertically striated. The edges are sometimes rounded and appear fused. Also occurs in compact, fibrous, nodular, reniform, botryoidal, or earthy masses.

Imperfect basal and prismatic cleavages. Conchoidal fracture. Brittle. Hardness 5, massive varieties sometimes 4.5. Specific gravity 3.16 to 3.23. Vitreous luster, on fracture surfaces more or less greasy. Sometimes colorless and transparent, but usually opaque and colored brown, green, gray, yellow, violet red, or white. Streak white. May phosphoresce when heated.

The chemical composition varies greatly. Apatite is essentially an orthophosphate of calcium containing fluorine, chlorine, or hydroxyl, so that the following formulas have been assigned to it: $\text{Ca}_5\text{F}(\text{PO}_4)_3$, $\text{Ca}_5\text{Cl}(\text{PO}_4)_3$, and $\text{Ca}_5(\text{Cl}, \text{F}, \text{OH})(\text{PO}_4)_3$. Fluorine usually predominates, hence, *fluor-apatite* is more common than *chloro-apatite*. Varying amounts of magnesium, manganese, and iron may be present. Fusible with difficulty. Moistened with sulphuric acid, it imparts a green color to the flame. Easily soluble in acids. The nitric acid solution of apatite yields a heavy yellow precipitate with ammonium molybdate.

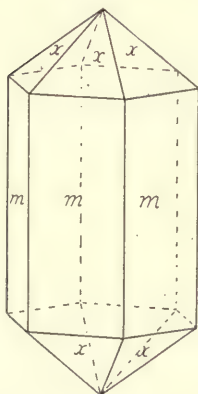


FIG. 99.

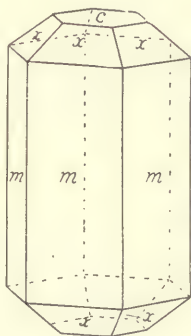


FIG. 100.

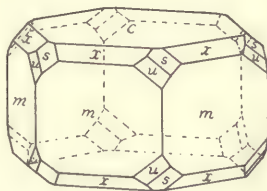


FIG. 101.

There are several varieties of apatite:

(1) *Ordinary Apatite*. This includes the crystallized, cleavable, and granular varieties.

(2) *Asparagus Stone*. A yellowish green variety occurring in Spain.

(3) *Phosphorite*. Fibrous, scaly, or concretionary masses, often with a concentric structure.

(4) *Osteolite*. This is a earthy, more or less altered apatite.

(5) *Guano*. Animal excrement, chiefly of birds, rich in phosphoric acid. Gray to brown in color and porous, granular, or compact in structure.

(6) *Phosphate Rock*. This is an impure, massive variety containing about 15 to 40% of P_2O_5 . It is gray, white, brown, or black in color and may occur in beds, nodules, or as concretions. Hardness varies from 2 to 5.

Apatite is a common, accessory constituent of many of the igneous rocks. It is also an associate of metalliferous ore deposits, especially those of magnetite and cassiterite, page 81. Apatite is also found in granular limestones. It is present in small quantities, from 0.02% up, in nearly all types of rocks.

Some important localities are Ehrenfriedersdorf, Saxony; Schlaggen-

wald, Bohemia; St. Gotthard, Switzerland; Arendal, Norway; Knappenwand, Tyrol; Jumilla, Spain; Luxullian, Cornwall, England. Large deposits occur in Lanark, Leeds, Renfrew, and Frontenac Counties, Ontario, and in Ottawa County, Quebec, Canada.

In the United States apatite is found at Norwich and Bolton, Mass.; St. Lawrence and Jefferson Counties, N. Y.; Chester Co., Pa.; and Alexander County, N. C.

Extensive deposits of phosphate rock or *bone phosphate* occur in Florida, South Carolina, Tennessee, Pennsylvania, Arkansas, and Alabama. In 1908 the United States produced 2,386,138 long tons of phosphate rock valued at \$11,399,124. This was obtained principally from Florida, South Carolina, and Tennessee.

Phosphate rock is used in large quantities in the manufacture of fertilizers. Its phosphoric acid content is rendered available by treatment with sulphuric acid. Apatite is also used to some extent in fertilizers and as a source of phosphorus.

PYROMORPHITE, $\text{Pb}_5\text{Cl}(\text{PO}_4)_8$.

Hexagonal system, hexagonal bipyramidal class. $a : c = 1 : 0.7362$. Small crystals resembling those of apatite (Figures 99 and 100). The common forms are the unit prism m and bipyramid x of the first order, and the basal pinacoid c . The prism faces are sometimes striated horizontally. The symmetry of the hexagonal bipyramidal class has been proven by means of etch figures only. Crystals are sometimes rounded and barrel-shaped. Occurs also in botryoidal and reniform aggregates, disseminated, and in crusts.

Conchoidal to uneven fracture. Brittle. Hardness 3.5 to 4. Specific gravity 6.9 to 7.1, if much calcium is present it may be as low as 5.9. Greasy, adamantine luster. Translucent to opaque. White to pale yellow streak. Usually some shade of green in color, but may be yellow, gray, brown, orange, or white.

$\text{Pb}_5\text{Cl}(\text{PO}_4)_8$. May contain calcium, fluorine, or arsenic. On charcoal it fuses to a globule which on cooling assumes a polyhedral form with a crystalline structure. Yields in the reducing flame a coating and globule of lead. Soluble in nitric acid. Occurs as a pseudomorph after galena and cerussite.

Pyromorphite is generally a secondary mineral formed from the decomposition of lead ores with which it is commonly associated. It occurs in the Freiberg district of Saxony; Clausthal, Hartz Mts.; Cornwall and Cumberland, England; Phoenixville, Pa.; Lubec and Lenox, Me.; and Sing Sing, N. Y.

Mimetite, $\text{Pb}_5\text{Cl}(\text{AsO}_4)_3$.

Hexagonal system, hexagonal bipyramidal class. $a : c = 1 : 0.7276$. Crystals resemble those of pyromorphite. Occurs also in globular, reniform, and earthy masses.

Imperfect pyramidal cleavage. Conchoidal to uneven fracture. Brittle. Hardness 3.5 to 4. Specific gravity 7 to 7.3. Greasy, adamantine luster. White streak. Yellow, brown, or white in color. Translucent.

$\text{Pb}_5\text{Cl}(\text{AsO}_4)_3$. *Campylite* contains 3 to 4% of P_2O_5 . *Hedyphane* is a variety with 10 to 14% of CaO . Yields fumes of arsenic trioxide and a globule of lead when heated on charcoal. Soluble in nitric acid and potassium hydroxide.

Like pyromorphite it is a secondary mineral and is always associated with lead ores. It is not as common as pyromorphite. Occurs in Cornwall, and Cumberland, England; Johanngeorgenstadt, Saxony; Příbram, Bohemia; Zacatecas, Mexico; and Phoenixville, Pa.

ENDLICHITE, $\text{Pb}_5\text{Cl}[(\text{As},\text{V})\text{O}_4]_3$, is an isomorphous mixture of mimetite and vanadinite. It occurs at Hillsboro, Sierra County, New Mexico.

Vanadinite, $\text{Pb}_5\text{Cl}(\text{VO}_4)_3$.

Hexagonal system, hexagonal bipyramidal class. $a : c = 1 : 0.7122$. Crystals are usually prismatic, resembling those of pyromorphite. Often show skeletal development. Occurs also in compact, fibrous aggregates with botryoidal or reniform surfaces.

Uneven to conchoidal fracture. Brittle. Hardness 2.75 to 3. Specific gravity 6.7 to 7.2. Yellow, brown, or red in color. White to pale yellow streak. Translucent to opaque. Resinous luster on fracture surfaces.

$\text{Pb}_5\text{Cl}(\text{VO}_4)_3$. May contain phosphorous or arsenic. Fuses easily. Reacts for lead and vanadium. Decrepitates when heated in a closed tube. Easily soluble in nitric acid.

Occurs associated with lead minerals, but never in large quantities; thus at Zimapan, Mexico; Ural Mountains; Wanlockhead, Scotland; Sing Sing, N. Y.; various places in Yuma, Maricopa, Pinal, and Yavapai Counties, Arizona.

It is a source of vanadium and its compounds.

Amblygonite, $\text{Li}(\text{AlF})\text{PO}_4$.

Triclinic, pinacoidal class. $a : b : c = 0.2454 : 1 : 0.4605$, $\alpha = 68^\circ 47'$, $\beta = 98^\circ 44'$, $\gamma = 85^\circ 52'$. Crystals are not common. Occur usually in cleavable, columnar, and compact masses. Polysynthetic twinning is common.

Basal, prismatic, and domatic cleavages inclined at angles of $70^\circ 30'$, $74^\circ 40'$, and $92^\circ 20'$. Conchoidal fracture. Brittle. Hardness 6. Specific gravity 3 to 3.11. Pearly to vitreous luster. White, green, blue, gray, yellow, or brownish in color. White streak. Translucent.

$\text{Li}(\text{AlF})\text{PO}_4$. A portion of the fluorine may be replaced by hydroxyl, and the lithium by sodium. Fuses easily with intumescence and colors the

flame carmine red. When powdered it is soluble in sulphuric or hydrochloric acids. Moistened with sulphuric acid it colors the flame momentarily bluish green.

Occurs at Penig, Saxony; Arendal, Norway; Hebron and Paris, Me.; Branchville, Conn.; and in large quantities at Pala, San Diego County, Cal. It is usually associated with lepidolite, petalite, or rubellite.

Amblygonite is a source of lithium.

OLIVENITE-WAGNERITE GROUPS

The members of these groups are basic fluorophosphates and the like, or isomorphous mixtures of them. The minerals of the olivenite group are orthorhombic, while those of the wagnerite group crystallize in the monoclinic system.

OLIVENITE GROUP

(*Orthorhombic System*)

	<i>a</i>	<i>b</i>	<i>c</i>
LIBETHENITE, $\text{Cu}(\text{Cu.OH})\text{PO}_4$.	Bipyramidal Class 0.7019	: 1	: 0.9601
ADAMITE, $\text{Zn}(\text{Zn.OH})\text{AsO}_4$.	Bipyramidal Class 0.7158	: 1	: 0.9733
OLIVENITE, $\text{Cu}(\text{Cu.OH})\text{AsO}_4$.	Bipyramidal Class 0.6726	: 1	: 0.9396
DESCLOIZITE, $(\text{Pb,Zn})(\text{Pb.OH})\text{VO}_4$.	Bipyramidal Class 0.6367	: 1	: 0.8046

WAGNERITE GROUP

(*Monoclinic System*)

	<i>a</i>	<i>b</i>	<i>c</i>	β
HERDERITE, $\text{Ca}(\text{Be.OH})\text{PO}_4$.	Prismatic Class 0.6307	: 1	: 0.4274,	90° 6'
WAGNERITE, $\text{Mg}(\text{Mg.F})\text{PO}_4$.	Prismatic Class 1.9138	: 1	: 1.5054,	108° 7'
TRIPLITE, $\text{Fe}(\text{Fe.F})\text{PO}_4$.			?	
TRIPLOIDITE, $\text{Mn}(\text{Mn.OH})\text{PO}_4$.	Prismatic Class 1.8571	: 1	: 1.4944,	108° 14'
ADELITE, $\text{Ca}(\text{Mg.OH})\text{AsO}_4$.	Prismatic Class 2.1978	: 1	: 1.5642,	106° 45'
TILASITE, $\text{Ca}(\text{Mg.F})\text{AsO}_4$.			?	
SARKINITE, $\text{Mn}(\text{Mn.OH})\text{AsO}_4$.	Prismatic Class 2.0013	: 1	: 1.5880,	117° 46'

Adelite, tilasite, and sarkinite are very rare.

LIBETHENITE, $\text{Cu}(\text{Cu.OH})\text{PO}_4$.

Orthorhombic, bipyramidal class. $a : b : c = 0.7019 : 1 : 0.9601$. Small crystals, approximately octahedral in habit and well developed. Often in druses. Also reniform, globular, and compact.

Very indistinct, brachy and macropinacoidal cleavages. Conchoidal to uneven fracture. Brittle. Hardness 4. Specific gravity 3.6 to 3.8. Resinous luster. Translucent. Dark olive green in color. Streak olive green.

$\text{Cu}(\text{Cu.OH})\text{PO}_4$. May contain some arsenic. Occurs at Libethen, Hungary; Nijni-Tagilak, Ural Mts.; Cornwall, England; Bolivia; Chile.

ADAMITE, $\text{Zn}(\text{Zn.OH})\text{AsO}_4$. Occurs in very small, orthorhombic crystals. Hardness 3.5. Specific gravity 4.35. Transparent. Vitreous luster. Yellow, violet, or colorless. Varieties containing cobalt are usually rose red, those with copper green. Found at Chañarcillo, Chile; Cap Garonne, France; Laurium, Greece.

OLIVENITE, $\text{Cu}(\text{Cu.OH})\text{AsO}_4$.

Orthorhombic, bipyramidal class. $a : b : c = 0.6726 : 1 : 0.9396$. Prismatic and acicular crystals. The prism angle $87^\circ 40'$. Occurs also in reniform and botryoidal masses with a fibrous or earthy structure, and often with a velvety surface.

No pronounced cleavage. Conchoidal to uneven fracture. Brittle. Hardness 3. Specific gravity 4.1 to 4.6. Adamantine, vitreous, or pearly luster. Subtransparent to translucent. Streak olive green to brown. Various shades of green in color, may also be brown, yellow, or grayish white.

Occurs in Cornwall and Cumberland, England; Nijni-Tagilak, Ural Mts.; Libethen, Hungary; Tintic district, Utah.

DESCLOIZITE, $(\text{Pb}, \text{Zn})(\text{Pb.OH})\text{VO}_4$, occurs in very small, orthorhombic crystals which usually possess drusy or warty surfaces; also massive. Hardness 3.5. Specific gravity 5.9 to 6.2. Orange, brownish red, or grayish streak. Cherry to brownish red, light or dark brown, or black in color. Found in the Argentine Republic; Lake Valley, Sierra County, New Mexico; Tombstone and other places in Arizona. Not a common mineral.

HERDERITE, $\text{Ca}(\text{Be.OH})\text{PO}_4$.

Monoclinic, prismatic class. $a : b : c = 0.6307 : 1 : 0.4274$, $\beta = 90^\circ 6'$. Occurs in prismatic crystals, often highly modified. The prism angle is $63^\circ 39'$. Pseudo-orthorhombic on account of complex twinning.

Conchoidal fracture. Brittle. Hardness 5. Specific gravity 3. Vitreous luster. Colorless or pale yellow. Transparent.

$\text{Ca}(\text{Be.OH})\text{PO}_4$. The hydroxyl may be replaced by fluorine. Liberates acid water when heated to a high temperature in a closed tube. Phosphoresces with an orange yellow color. Turns blue when treated with cobalt nitrate solution. Soluble in acids.

Occurs in Stoneham, Auburn, and Hebron, Maine.

WAGNERITE, $\text{Mg}(\text{Mg.F})\text{PO}_4$.

Monoclinic, prismatic class. $a : b : c = 1.9138 : 1 : 1.5054$, $\beta = 108^\circ 7'$. Short and long columnar crystals with vertical striations. Often highly modified. Also massive.

Imperfect prismatic, orthopinacoidal, and basal cleavages. Conchoidal fracture.

Hardness 5 to 5.5. Specific gravity 3 to 3.15. Greasy, vitreous luster. Translucent. Various shades of yellow, gray, flesh red, and green in color. White streak.

$\text{Mg}(\text{Mg.F})\text{PO}_4$. May contain small amounts of iron and calcium replacing magnesium. Fuses with difficulty to a grayish green enamel. Moistened with sulphuric acid it imparts a bluish green color to the flame. The powder is slowly soluble in nitric acids with an evolution of hydrofluoric acid.

Found sparingly at Werfen, Salzburg, Austria.

TRIPLITE, $\text{Fe}(\text{Fe.F})\text{PO}_4$. Probably monoclinic and isomorphous with wagnerite. Occurs only in imperfect, crystalline masses with two cleavages at right angles to each other. Conchoidal to uneven fracture. Hardness 4 to 5.5. Specific gravity 3.5 to 3.8. Greasy luster. Chestnut brown to black in color. Streak yellow gray to brown. Translucent. Found at Limoges, France; Helsingfors, Finland; Stoneham, Me.; Branchville, Conn.

Triploidite, $(\text{Mn,Fe})[(\text{Mn,Fe})\text{OH}]\text{PO}_4$, may be considered a triplite in which manganese predominates and fluorine has been replaced by hydroxyl. Prismatic crystals are rare; usually found in crystalline aggregates. Hardness 4.5 to 5. Specific gravity 3.7. Vitreous to greasy adamantine luster. Transparent to translucent. Yellow or reddish brown in color. Occurs at Branchville, Conn.

CLINOCLASITE, **APHANESE**, $(\text{Cu.OH})_3\text{AsO}_4$. Monoclinic, prismatic class. $a : b : c = 1.9069 : 1 : 3.8507$, $\beta = 99^\circ 30'$. Small, prismatic crystals. The prism angle is 124° . Often arranged in spherical groups. Also hemispherical or reniform masses with a radial fibrous structure. Very perfect basal cleavage. Brittle. Hardness 2.5 to 3. Specific gravity 4.2 to 4.4. Pearly luster on cleavage surfaces, otherwise vitreous. Translucent. Externally black blue-green in color, internally verdigris-green. Bluish green streak. Occurs with copper minerals in Cornwall and Devonshire, England; Sayda, Saxony; and Tintic district, Utah.

DUFRENITE, **Kraurite**, $\text{Fe}_2(\text{OH})_3\text{PO}_4$. Orthorhombic, $a : b : c = 0.8734 : 1 : 0.4260$. Crystals are small, rare, and apparently cubical in habit. The surfaces are usually rounded. Occurs also in spherical and reniform aggregates with a radial fibrous structure.

Distinct macropinacoidal cleavage. Very brittle. Hardness 3.5 to 4. Specific gravity 3.3 to 3.5. Slightly greasy luster. Various shades of green in color, on exposure turns yellow or brown. Yellowish green streak. Translucent to nearly opaque. * Occurs with iron minreals at Limoges, France; Hirschberg, Westphalia; Allentown, N. J.; Rockbridge, Va.

Lazulite, $\text{Mg}(\text{Al.OH})_2(\text{PO}_4)_2$.

Monoclinic, prismatic class. $a : b : c = 0.9747 : 1 : 1.6940$, $\beta = 91^\circ 58'$. Well developed crystals are not common. They are usually acute pyramidal in habit, sometimes tabular or domatic. Also granular to compact masses.

Indistinct prismatic cleavage. Uneven fracture. Brittle. Hardness 5



to 6. Specific gravity 3 to 3.12. Vitreous luster. Translucent to opaque. Various shades of blue in color, usually azure blue. White streak.

$\text{Mg}(\text{Al.OH})_2(\text{PO}_4)_2$. Magnesium may be replaced by iron and calcium. Yields water in closed tube and turns white. The blue color may be restored by treatment with cobalt nitrate solution. Moistened with sulphuric acid it imparts a bluish green color to the flame. Not attacked by acids.

Occurs at Werfen, Salzburg, Austria; various places in Styria; Horrsjöberg, Sweden; Crowder's Mt., Gaston County, N. C.; and Graves Mt., Lincoln County, Ga.

3. HYDRATED COMPOUNDS

The hydrated compounds include normal, acid, and basic salts. Very few of these minerals occur in large quantities.

Struvite, $\text{NH}_4\text{MgPO}_4 \cdot 6\text{H}_2\text{O}$.

Orthorhombic, pyramidal class. $a : b : c = 0.5667 : 1 : 0.9121$. Excellent example of hemimorphism. Perfect basal cleavage. Translucent to opaque. Vitreous luster. Colorless, but often yellow or pale brown. Hardness 1.5 to 2. Specific gravity 1.66 to 1.75. Found in sewers and guano deposits.

VIVIANITE GROUP

This group embraces the ortho salts of magnesium, iron, cobalt, nickel, and zinc containing eight molecules of water. Chemically they are isomorphous, but only on three of them have crystallographic investigations been made. These have been referred to the monoclinic prismatic class.

	a	b	c	β
BOBIERRITE, $\text{Mg}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$.		?		103° Approx.
Vivianite , $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$.	0.7498	: 1	: 0.7017,	$104^\circ 26'$
HOERNESITE, $\text{Mg}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.		?		
SYMPLESITE, $\text{Fe}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.	0.7806	: 1	: 0.6812,	$107^\circ 13'$
Erythrite , $\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.	0.7937	: 1	: 0.7356,	$105^\circ 9'$
Annabergite , $\text{Ni}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.		?		
CABRERITE, $(\text{Ni,Mg})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.		?		
KÖTTIGITE, $(\text{Zn,Co})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.		?		

These minerals are all secondary formations and do not occur very abundantly.

BOBIERRITE. $\text{Mg}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$, occurs in aggregates of very small, white monoclinic crystals and in reniform masses in guano at Mejillones, Chile

Vivianite, Blue Iron-earth, $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.7498 : 1 : 0.7017$, $\beta = 104^\circ 26'$. Crystals are usually thin prismatic. Occurs also in reniform and globular aggregates with a radial, fibrous structure; often earthy and may then be known as *blue iron-earth*.

Clinopinacoidal cleavage. Sectile. Thin laminae are flexible. Hardness 1.5 to 2. Specific gravity 2.6 to 2.7. Translucent. On cleavage surfaces pearly or metallic pearly luster, elsewhere vitreous. When fresh white or colorless; on exposure, due to the formation of a basic ferric phosphate, it gradually turns blue. Colorless or bluish white streak, which deepens rapidly to indigo blue. Transparent to translucent, opaque after exposure. Strongly pleochroic.

$\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$. Fuses easily and colors the flame bluish green. Yields on charcoal a magnetic globule. Soluble in hydrochloric acid.

Occurs as a secondary mineral in association with iron compounds, which have been acted upon by circulating waters containing phosphoric acid. It is sometimes found in bones, shells, and roots of trees. Some important localities are Cornwall and Devonshire, England; Bodenmais, Bavaria; Anglars and elsewhere, France; Middletown, Del.; Allentown, N. J.; Eddyville, Ky.

HOERNESITE, $\text{Mg}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$. Occurs in good sized crystals, often arranged in stellate groups. Perfect clinopinacoidal cleavage. Very soft, 0.5 to 1. Specific gravity 2.47. Flexible, resembles talc or gypsum. Snow-white to pale rose red in color. Pearly luster. Occurs at Banat and Nagyg, Hungary.

SYMPLESITE, $\text{Fe}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$, occurs in extremely small, acicular crystals which are usually arranged in spherical groups. Very perfect clinopinacoidal cleavage. Brittle. Hardness 2.5. Specific gravity 2.96. Pale blue or greenish in color. Found at Lobenstein, Voigtland and Felsöbánya, Hungary.

Erythrite, Cobalt Bloom, $\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.7937 : 1 : 0.7356$, $\beta = 105^\circ 9'$. Crystals are generally very small, acicular, and vertically striated. Sometimes arranged in spherical and stellate groups. Occurs often in globular, reniform, and earthy masses; also as a coating.

Very perfect clinopinacoidal cleavage. Sectile and flexible, especially in thin laminae. Hardness 1.5 to 2.5. Specific gravity 2.95. Crystals possess a pearly luster on the cleavage surfaces, otherwise adamantine to vitreous. Transparent to subtranslucent. Crimson to peach red in color, due to decomposition pearly to greenish gray. Pale red streak.

$\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$. Yields water in a closed tube and turns blue. Acid solutions are red.

Erythrite is a decomposition product of the arsenides of cobalt. It is commonly found in association with cobaltite, smaltite, and chloanthite in the Freiberg district, Saxony, and rather abundantly in the Cobalt Silver district of Ontario.

Annabergite, Nickel Bloom, $\text{Ni}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.

Monoclinic. Occurs only in earthy, somewhat crystalline crusts and masses. Very soft. Specific gravity 3 to 3.1. Apple green in color. It is a decomposition product of minerals containing nickel and arsenic, such as niccolite and chloanthite. Found in the Freiberg district, Saxony, and the Cobalt district, Ontario.

CABRERITE, $(\text{Ni}, \text{Mg})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$, is a variety of annabergite containing considerable magnesium.

KÖTTIGITE, $(\text{Zn}, \text{Co})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$, is a zinciferous variety of erythrite.

SCORODITE GROUP

This group embraces the orthophosphates and arsenates of aluminium and trivalent iron containing two molecules of water of crystallization. These minerals crystallize in the orthorhombic bipyramidal class.

	a	b	c
VARISCITE, $\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$.	0.8648	1	?
STRENGITE, $\text{FePO}_4 \cdot 2\text{H}_2\text{O}$.	0.8652	1	0.9827
Scorodite , $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$.	0.8687	1	0.9536

VARISCITE, $\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$. Orthorhombic. Occurs in reniform crusts with a fine crystalline structure. Sometimes apparently amorphous. Conchoidal fracture. Greasy feel. Hardness 4 to 5. Apple green to colorless. Translucent. Dull waxy luster. Found in Montgomery County, Ark., and in nodular masses in Utah.

STRENGITE, $\text{FePO}_4 \cdot 2\text{H}_2\text{O}$. Orthorhombic, bipyramidal class. $a : b : c = 0.8652 : 1 : 0.9827$. Usually found in spherical and botryoidal forms with a radial fibrous structure. Crystals are rare. Hardness 3 to 4. Specific gravity 2.87. Vitreous luster. Pale red to almost colorless. Occurs near Giessen, Germany, and in Rockbridge County, Va.

BARRANDITE, $(\text{Fe}, \text{Al})\text{PO}_4 \cdot 2\text{H}_2\text{O}$, is a variety of strengite containing aluminium.

Scorodite, $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$.

Orthorhombic, bipyramidal class. $a : b : c = 0.8687 : 1 : 0.9536$. Small, pyramidal or prismatic crystals, often in druses. Also botryoidal and reniform masses with a fibrous structure, or as earthy crusts.

Crystals possess an important prismatic cleavage. Conchoidal to uneven fracture. Hardness 3.5 to 4. Specific gravity 3.1 to 3.3. Greasy luster on cleavage surfaces, elsewhere vitreous. Grayish white streak. Translucent. Pale green to black or blue green in color; more rarely blue, red, or brown.

$\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$. Yields water in a closed tube and turns yellow. Easily fusible and colors flame blue. Soluble in hydrochloric acid.

Occurs commonly with limonite or arsenopyrite. Found at Johanngeorgenstadt, Schneeberg, and Schwarzenberg, Saxony; Cornwall, England; Nerchinsk, Siberia; Brazil.

Pharmacolite, $\text{CaHAsO}_4 \cdot 2\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.6137 : 1 : 0.3622$, $\beta = 96^\circ 47'$. Crystals are not common. Usually in spherical masses and crusts with a fine fibrous structure. Crystals possess a perfect clinopinacoidal cleavage. Uneven fracture. Thin laminae are flexible. Hardness 2 to 2.5. Specific gravity 2.64 to 2.73. Vitreous luster, pearly on cleavage surfaces. Color white to grayish, sometimes reddish or green, due to admixture of erythrite or annabergite. White streak. Translucent to opaque.

Occurs commonly as a coating on arsenical minerals at St. Andreasberg, Hartz Mountains; Joachimsthal, Bohemia.

EUCHROITE, $\text{Cu}(\text{Cu.OH})\text{AsO}_4 \cdot 3\text{H}_2\text{O}$. Orthorhombic, bipyramidal class. $a : b : c = 0.6c88 : 1 : 1.0379$. Short columnar crystals, often vertically striated and arranged in druses or crusts. The prism angle is $62^\circ 40'$. Crystals are comparatively large.

Indistinct prismatic cleavage. Conchoidal fracture. Brittle. Hardness 3.5 to 4. Specific gravity 3.3 to 3.4. Vitreous luster. Transparent to translucent. Emerald green in color, resembles diopside, page 211. Pale green streak. Found in mica schist at Libethen, Hungary.

CHALCOPHYLLITE, $(\text{Cu.OH})_3\text{AsO}_4 \cdot \text{Cu}(\text{OH})_2 \cdot 3\frac{1}{2}\text{H}_2\text{O}$. Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 2.5536$. Crystals are tabular, parallel to the basal pinacoid. Occurs also massive and in druses.

Perfect basal cleavage. Hardness 2. Specific gravity 2.4 to 2.66. Transparent to translucent. Pearly luster on cleavage surfaces, otherwise vitreous to subadamantine. Blue, emerald, or verdigris-green in color. Pale green streak. May contain Al_2O_3 , P_2O_5 , and FeO . Found at Redruth, Cornwall, England; Sayda, Saxony; Nijni-Tagilak, Ural Mountains.

PHARMACOSIDERITE, $\text{Fe}(\text{Fe.OH})_3(\text{AsO}_4)_3 \cdot 6\text{H}_2\text{O}$.

Cubic, hextetrahedral class. Small crystals consisting commonly of a combination of the cube, rhombic dodecahedron, and the positive and negative tetrahedrons. The crystal faces are often somewhat rounded. Also granular and massive.

Imperfect cubical cleavage. Conchoidal to uneven fracture. Hardness 2.5. Specific gravity 2.9 to 3. Adamantine vitreous luster, on fracture surfaces greasy. Transparent to translucent. Various shades of green, brown, and yellow in color. Light yellowish green streak. Usually occurs with limonite and ores of copper. Found in Cornwall and Cumberland, England; Victoria, Australia; Schneeberg, Saxony; Tintic district, Utah.

Wavellite, $(\text{Al.OH})_3(\text{PO}_4)_2 \cdot 5\text{H}_2\text{O}$.

Orthorhombic, bipyramidal class. $a : b : c = 0.5573 : 1 : 0.4084$. Well developed crystals are very rare. Commonly in hemispherical or globular masses made up of concentric layers and possessing a radial fibrous structure.

Crystals possess fairly good brachypinacoidal and domatic cleavages. Conchoidal to uneven fracture. Brittle. Hardness 3.5 to 4. Specific gravity 2.3 to 2.4. Vitreous luster, on fracture surfaces more or less pearly or resinous. Translucent. May be colorless, but is usually gray, yellow, green, brown, blue, or black. White streak.

$(\text{Al.OH})_3(\text{PO}_4)_2 \cdot 5\text{H}_2\text{O}$. May also be written $3\text{Al}_2\text{O}_3 \cdot 2\text{P}_2\text{O}_5 \cdot 13\text{H}_2\text{O}$. There may be some variations in the amount of water of crystallization present. Fluorine may replace some of the hydroxyl. Infusible. Imparts a green color to the flame. Turns blue when treated with cobalt nitrate solution. Soluble in hydrochloric acid or potassium hydroxide.

Wavellite is a secondary mineral formed by the action of circulating waters containing phosphoric acid upon rocks and minerals rich in alumina. It is found on the surfaces of such rocks, or lining the cracks or cavities in the same. Some localities are Devonshire and Cornwall, England; Freiberg district, Saxony; Bohemia; York County, Pa.; Montgomery County, Ark.; Silver Hill, N. C.

Turquois, Turquoise, $\text{Al}_2(\text{OH})_3\text{PO}_4 \cdot \text{H}_2\text{O}$.

Apparently amorphous. Never crystallized, generally in reniform, botryoidal, or stalactitic masses; sometimes in veins, crusts or coatings, disseminated grains, or rolled and rounded pebbles.

No cleavage. Conchoidal fracture. Brittle. Hardness 6. Specific gravity 2.6 to 2.8. Generally opaque. Slightly waxy luster. Various shades of blue or green in color. White or slightly greenish streak.

$\text{Al}_2(\text{OH})_3\text{PO}_4 \cdot \text{H}_2\text{O}$. Copper and iron may be present in small amounts. Analyses vary considerably. According to Penfield the formula should be written: $[\text{Al}(\text{OH})_2, \text{Fe}(\text{OH})_2, \text{Cu}(\text{OH}), \text{H}]_3\text{PO}_4$. That is, turquois is referred to the orthophosphoric acid, H_3PO_4 , in which hydrogen has been almost entirely replaced by the monovalent groups $\text{Al}(\text{OH})_2$, $\text{Fe}(\text{OH})_2$, and Cu.OH . When heated in a closed tube it yields water and at first turns black, afterward brown. Infusible. Colors the flame green. Soluble in acids.

Turquois is a secondary mineral and is often associated with limonite. It occurs in trachyte near Nischapur, Khodrassan, Persia; Los Cerillos, also in the Burro Mountains, Gaston County, N. M.; Turquois Mt., Arizona.

Used for gem purposes.

CHILDRENITE, $(\text{Fe}, \text{Mn})\text{Al}(\text{OH})_2\text{PO}_4 \cdot \text{H}_2\text{O}$.

Orthorhombic, bipyramidal class. $a : b : c = 0.7776 : 1 : 0.5254$. Small, tabular or bipyramidal crystals; often in druses or crusts.

Imperfect macropinacoidal cleavage. Uneven fracture. Hardness 4.5 to 5. Specific gravity 3.18 to 3.24. Greasy, vitreous luster. Translucent. Yellowish white to brownish black in color. Occurs at Tavistock, Devonshire, and St. Austle, Cornwall, England; Hebron, Me.

TORBERNITE GROUP

The minerals of this group are phosphates and arsenates of uranyl, UO_2 , and the bivalent elements, calcium, barium, and copper. They contain eight molecules of water of crystallization. Although they do not all crystallize in the same system, their elements of crystallization are very similar.

AUTUNITE, $\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$. Orthorhombic $a : b : c$ 0.9876 : 1 : 2.8530
 URANOSPINIT, $\text{Ca}(\text{UO}_2)_2(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$.

Orthorhombic 1 (?) : 1 : 2.9123

URANOCIRCITE, $\text{Ba}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$.

?

TORBERNITE, $\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$. Tetragonal 1.0000 : 1 : 2.9382

ZEÜNERITE, $\text{Cu}(\text{UO}_2)_2(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$. Tetragonal 1.0000 : 1 : 2.9123

These minerals are alteration products of uraninite or pitch-blende, page 142. Uranospinit, uranocircite, and zeünerite are very rare.

AUTUNITE, Lime Uranite, $\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$.

Orthorhombic. Crystals are tabular and quadratic in outline. Also foliated and micaceous.

Perfect basal cleavage. Hardness 1 to 2.5. Specific gravity 3 to 3.2. Pearly luster on cleavage surfaces, otherwise subadamantine. Translucent. Lemon to sulphur yellow in color, resembling orpiment. Pale yellow streak. Brittle.

Occurs with uraninite at Johanngeorgenstadt and Schneeberg, Saxony; Limoges, France; Cornwall, England; Middletown and Branchville, Conn.; Mitchell County, N. C.; Black Hills, S. Dak.; Chesterfield, Mass.

Autunite is not as common as torbernite.

TORBERNITE, Copper Uranite, $\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$.

Tetragonal. Crystals possess a quadratic outline, and may be tabular or acute bipyramidal in habit. Also micaceous, foliated, or in crusts.

Perfect basal cleavage. Hardness 2 to 2.5. Specific gravity 3.5 to 3.6. Vitreous luster, pearly on cleavage surfaces. Translucent. Green to emerald green in color. Pale green streak. Brittle.

Contains when fresh twelve molecules of water of crystallization.

Commonly associated with limonite. Occurs at Johanngeorgenstadt and Schneeberg, Saxony; Cornwall, England; Limoges, France; Joachimsthal, Bohemia.

IX. SILICATES

INCLUDING TITANATES, ZIRCONATES, AND THORATES

The silicates are by far the most abundant and important minerals of this division. Many of them—pyroxenes, amphiboles, micas, and feldspars—are of very great importance as rock minerals. The few titanates, zirconates, and thorates, which have thus far been observed in nature, are included here because of the close chemical relationship existing between them and the silicates. For the most part, the composition of all the members of this division is rather complex.

The *orthosilicic acid* H_4SiO_4 may be considered the basis for the derivation of the other silicic acids of the group. By the loss of a molecule of water, it passes over to the *metasilicic acid* H_2SiO_3 , and by the loss of water from several molecules, the more complex acids may be derived. These may be arranged as follows:

Orthosilicic acid,	H_4SiO_4 .
Diorthosilicic acid,	$\text{H}_6\text{Si}_2\text{O}_7$, $(2\text{H}_4\text{SiO}_4 - \text{H}_2\text{O})$.
Trisilicic acid,	$\text{H}_4\text{Si}_3\text{O}_8$, $(3\text{H}_4\text{SiO}_4 - 4\text{H}_2\text{O})$.
Tetrasilicic acid,	$\text{H}_4\text{Si}_4\text{O}_{10}$, $(4\text{H}_4\text{SiO}_4 - 6\text{H}_2\text{O})$.
Pentasilicic acid,	$\text{H}_4\text{Si}_5\text{O}_{12}$, $(5\text{H}_4\text{SiO}_4 - 8\text{H}_2\text{O})$.

Polysilicic acids are those which are still more complex. By eliminating water from two molecules of the metasilicic acid, the important dimetasilicic acid $\text{H}_2\text{Si}_2\text{O}_5$ may be obtained.

In many cases it is difficult to interpret a chemical analysis of a silicate correctly, because the substance may be considered as a salt of several silicic acids.

Formerly, silicates were classified according to the ratio existing between the number of oxygen atoms held by the basic and acid elements, thus:

	RATIO			
Unisilicates,	1 : 1,	2MgO,	SiO_2 ,	Olivine.
Bisilicates,	1 : 2,	MgO,	SiO_2 ,	Enstatite.
Trisilicates,	1 : 3,	$\left\{ \begin{array}{l} \text{K}_2\text{O}, \\ \text{Al}_2\text{O}_3, \end{array} \right.$	6 SiO_2 ,	Orthoclase.
Tetrasilicates,	1 : 4,	$\left\{ \begin{array}{l} \text{Li}_2\text{O}, \\ \text{Al}_2\text{O}_3, \end{array} \right.$	8 SiO_2 ,	Petalite.

Silicates are in general easily distinguished from many of the other minerals by their hardness, lack of characterizing colors, transparency, non-metallic luster, and uncolored streak. They will be considered in the following order given by Groth:

- (1) Basic silicates.
- (2) Orthosilicates.
- (3) Intermediate silicates.
- (4) Metasilicates.
- (5) Polysilicates.
- (6) Zeolites.
- (7) Amorphous silicates containing water.

STAUROLITE, $\text{HFeAl}_2\text{Si}_2\text{O}_{11}$

Orthorhombic, bipyramidal class. $a : b : c = 0.4803 : 1 : 0.6761$. Generally in well developed prismatic crystals, sometimes rather large. Simple crystals usually show a combination of the unit prism m , the basal and brachypinacoids c and b , and the macrodome q , Figure 102. Penetration twins according to two laws are very common. (1) The twinning plane is parallel to a face of the brachydome, $m = 3/2$. The individual crystals interpenetrate at an angle of about 90° , forming *cross-* or *plus-shaped twins*, Figure 103. (2) The modified brachybipyramid (n and $m = 3/2$) acts as

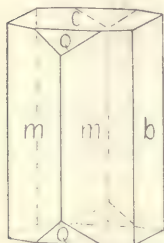


FIG. 102

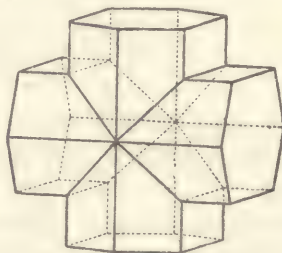


FIG. 103

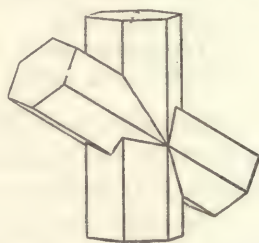


FIG. 104

the twinning plane. The crystals intersect at an angle of about 60° , and such twins are sometimes termed *X-shaped twins*, Figure 104. Fresh crystals usually possess bright and smooth faces.

Distinct brachypinacoidal cleavage. Conchoidal to uneven fracture. Brittle. Hardness 7 to 7.5. Specific gravity 3.4 to 3.8. Vitreous luster, dull when crystals are somewhat altered. Greasy luster on fracture surfaces. Translucent to opaque. Usually reddish brown in color, but may be brownish black, yellowish brown, or gray. Colorless streak when fresh.

$\text{Fe}(\text{AlO})_4(\text{Al.OH})(\text{SiO}_4)_2$. Composition varies greatly— SiO_2 from

27.9% to 51.3%. May contain ferrous iron, magnesium, manganese, and zinc. *Nordmarkite* is a manganiferous variety from Nordmarken, Sweden. Infusible. Fuses with difficulty with borax or salt of phosphorus. Varieties containing manganese fuse readily to a black magnetic glass. Not attacked by acids, not even cold hydrofluoric acid.

Occurs generally in metamorphic rocks, especially gneiss, mica schist, and slates. The common associates are cyanite, garnet, tourmaline, and sillimanite. At Mt. Campione in the St. Gotthard district of Switzerland it occurs with cyanite in paragonite schist; also in various places in Tyrol; Stryia; Bavaria; and in Brittany, France.

Some of the principal localities in the United States are Fannin Co., Ga.; Cherokee Co., N. C.; Chesterfield, Mass.; Franconia, N. H.; Windham, Me.; also in New York, Connecticut, and Pennsylvania.

Clear and transparent crystals are sometimes used for gem purposes.

DUMORTIERITE, $\text{HBAI}_8\text{Si}_3\text{O}_{20}$.

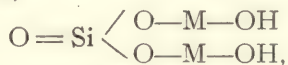
Orthorhombic, bipyramidal class. $a : b : c = 0.532 : 1 : ?$. Occurs in thin fibrous or columnar aggregates. The prism angle is 56° . Distinct macropinacoidal cleavage. Hardness 7. Specific gravity 3.3. Large specimens are opaque, isolated fibres transparent. Vitreous to silky luster. Deep blue, lavender blue, greenish blue to black in color. Bluish white streak. Strong pleochroism.

$\text{Al}(\text{AlO})_7(\text{BO})\text{H}(\text{SiO}_4)_3$. Infusible, but loses its color and turns white. Re-assumes its blue color when treated with cobalt nitrate solution. Mixed with potassium bisulphate and fluorite it imparts momentarily a green color to the flame. This reaction is difficult of execution.

Occurs disseminated in pegmatite veins. It is commonly associated with feldspar, quartz, muscovite, and cyanite. It is found at Wolfshau, Silesia; Beaumont, France; Harlem, N. Y.; Skamania County, Wash.; San Diego County, Cal.; and Clip, Yuma County, Arizona.

HEMIMORPHITE GROUP

This group embraces the two minerals hemimorphite and clinohedrite with the general formula,



in which M indicates zinc and calcium. In hemimorphite only zinc is present while in clinohedrite both zinc and calcium enter into the composition. Although the minerals do not crystallize in the same systems, their elements of crystallization show some similarity.

HEMIMORPHITE, $(\text{Zn.OH})_2\text{SiO}_3$, Orthorhombic, $a : b : c = 0.7835 : 1 : 0.4778$
 $\beta = 103^\circ 56'$.

CLINOHEDRITE, $(\text{Zn.OH})(\text{Ca.OH})\text{SiO}_3$, Monoclinic, $0.6826 : 1 : 0.3226$
 Both minerals show hemimorphic development.

HEMIMORPHITE, Calamine, $\text{H}_2\text{Zn}_2\text{SiO}_5$.

Orthorhombic, pyramidal class. $a : b : c = 0.7835 : 1 : 0.4778$. Usually in small, tabular or pyramidal crystals possessing a pronounced hemimorphic development, Figure 105. Over 45 forms have been observed on

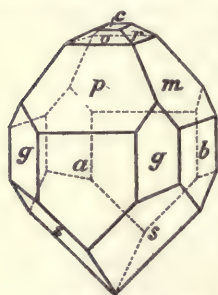


FIG. 105

hemimorphite. The common forms are the basal, brachy-, and macropinacoids c , b and a , unit prism g , the modified brachy- and macrodomes m and p (both having the coefficient m equal to 3), the unit brachy- and macrodomes r and o , and the lower brachypyrmaid s with coefficients n and m equal to 2. On tabular crystals the brachypinacoid b predominates. Vertical striations are often observed on the brachypinacoid. Supplementary twins with the basal pinacoid acting as the twinning plane are sometimes to be noted. Crystals are often arranged in sheaf-

like groups; also as druses, especially in cavities. May be fibrous, globular, botryoidal, stalactitic, granular, compact, or earthy.

Perfect prismatic cleavage. Uneven to conchoidal fracture. Brittle. Hardness 4 to 5. Specific gravity 3.3 to 3.5. Vitreous luster, sometimes adamantine. Translucent to transparent. Colorless, white, gray, brown, or blue. Streak white. Strongly pyroelectric.

$(\text{Zn.OH})_2\text{SiO}_3$. Almost infusible. Fusible with borax to a clear bead, which becomes cloudy on cooling. Yields water when heated in a closed tube. Gelatinizes with acids, even acetic acid. Soluble in concentrated potassium hydroxide. Occurs as a pseudomorph after calcite, galena, dolomite, fluorite, and pyromorphite.

It is usually found in limestones associated with sphalerite, smithsonite, galena, and the like. Although it is a common mineral, it is not as abundant as sphalerite. Some important localities are Aachen, Germany; Raibel and Bleiberg, Carinthia; Silesia; Cumberland and Derbyshire, England; Bohemia; Sardinia.

In the United States it occurs in fine crystalline masses in Sussex County, N. J.; Phoenixville and Friedensville, Pa.; Granby, Mo.; and Pulaski and Wythe counties, Va.

Hemimorphite is an important ore of zinc.

CLINOHEDRITE, $(\text{Zn.OH})(\text{Ca.OH})\text{SiO}_3$.

Monoclinic, domatic class. $a : b : c = 0.6826 : 1 : 0.3226$, $\beta = 103^\circ 56'$. Crystals are rather complex and show hemimorphic development. Hardness 5.5. Specific gravity 3.33. Colorless, white, or amethystine. Fuses with intumescence to a white enamel. Easily soluble in hydrochloric acid. Occurs with willemite, phlogopite, garnet, and axinite in the Tather Mine, near Franklin Furnace, N. J.

ANDALUSITE GROUP

The compound Al_2SiO_5 is trimorphous, and occurs as the minerals andalusite, sillimanite, and cyanite. The first two minerals crystallize in the orthorhombic system, while the third is triclinic. Andalusite and sillimanite are very closely related in many respects. They are considered salts of orthosilicic acid, whereas cyanite is thought to be derived from metasilicic acid.

ANDALUSITE, Al_2SiO_5 .

Orthorhombic, bipyramidal class. $a : b : c = 0.9856 : 1 : 0.7020$. Occurs usually in large, rough, columnar crystals. Often disseminated and, due to superficial alteration, covered with scales of mica or sericite. Figure 106 shows the common type of development. The combination consists of the unit prism m , basal pinacoid c , and the unit brachydome d . The prism angle is $89^\circ 12'$, which gives the crystals a tetragonal habit.

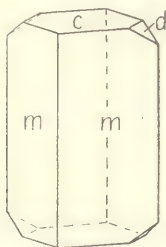


FIG. 106

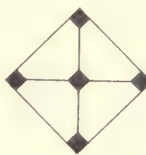


FIG. 107a



FIG. 107b

Chiastolite or Macle is a variety occurring in rounded prisms with a regular internal arrangement of carbonaceous impurities as shown in Figures 107a and 107b.

Distinct prismatic cleavage. Uneven fracture. Brittle. Hardness 7 to 7.5, somewhat softer on the surface. Specific gravity 3.1 to 3.2. Usually

dull and opaque, rarely with a vitreous luster and transparent. May be greenish, reddish gray, pearl gray, rose red, flesh red, or violet in color. Sometimes strongly pleochoic. White streak.

Al_2SiO_5 . The rational formula is often written $\text{Al}(\text{AlO})\text{SiO}_4$. *Man-gandalusite* is a variety containing some Mn_2O_3 .

Infusible. Turns blue when treated with cobalt nitrate solution. Not acted upon by acids. Alters to cyanite, mica, kaolinite, or dense talcose minerals resembling steatite. Changes to sillimanite when heated to a temperature of 1350° .

Occurs essentially in metamorphic rocks. It is commonly found in the contact zones of such igneous rocks as granites, syenites, nepheline syenites, and diorites, being the result of the alteration of clay slates and shales. It is often associated with sillimanite.

It is found in Andalusia, Spain; Tyrol; Bräunsdorf, Saxony; Wunsiedel, Bavaria; and in transparent crystals in Minas Geraes, Brazil.

In the United States, Westford, Lancaster, and Sterling, Mass., are important localities; also Litchfield and Washington, Conn.; Standish, Me., and elsewhere in the New England States; to some extent also in Pennsylvania and California.

Sillimanite, Fibrolite, Al_2SiO_5 .

Orthorhombic. $a : b : c = 0.970 : 1 : ?$. Usually in long, thin, needle-like crystals; or in fibrous or columnar masses with a radial structure. Crystals are not distinctly terminated. The prism angle is 69° . The prism faces are generally striated vertically and often more or less rounded.

Perfect macropinacoidal cleavage. Uneven fracture. Hardness 6 to 7. Specific gravity 3.2 to 3.25. Greasy vitreous luster; aggregates somewhat silky. Transparent to translucent. Yellowish gray, grayish white, grayish green, or brown in color.

Chemical composition and behavior are the same as for andalusite. Microscopic crystals are formed artificially in the manufacture of chinaware.

Occurs as an accessory constituent of gneisses, quartzites, mica schists, and other metamorphic rocks. It is sometimes associated with andalusite, iolite, zircon, or corundum. Some localities are Bodenmais, Bavaria; Freiberg, Saxony; various places in Tyrol; in secondary deposits in Minas Geraes, Brazil. In the United States sillimanite occurs at Worcester, Mass.; Norwich and Willimantic, Conn.; Westchester and Monroe counties, N. Y.; and Chester, Pa.

CYANITE, Disthene, Kyanite, Al_2SiO_5 .

Triclinic, pinacoidal class. $a : b : c = 0.8994 : 1 : 0.7090$, $\alpha = 90^\circ 5\frac{1}{2}'$, $\beta = 101^\circ 2'$, $\gamma = 105^\circ 44\frac{1}{2}'$. Generally in long, broad crystals without distinct terminations; or in coarsely bladed, columnar or fibrous masses. Crystals are sometimes curved and arranged radially. The common forms are the three pinacoids, and the right and left unit hemiprisms. Twins occur according to several laws. Of these laws the one in which the macropinacoid acts as the twinning plane is the most common. Polysynthetic twinning parallel to the basal pinacoid often causes the faces in the prism zone to be striated horizontally. Cyanite is sometimes found in sands and gravels, especially in Russia, India, and Brazil.

Very perfect macro- and perfect brachypinacoidal cleavages. Brittle. The hardness varies greatly with face and direction. On the macropinacoid, which is usually very large, it is least, 4 to 4.5, parallel to the length of the blades or crystals, and greatest, 6 to 7, in a direction perpendicular to the above. Specific gravity 3.5 to 3.7. Vitreous luster. Transparent to translucent. Generally blue, especially sky blue, in color; also grayish, white, yellow, green, brownish, or colorless. Often multicolored. *Rhätzite* is a fine fibrous, grayish to black variety.

Al_2SiO_5 . Chemical composition and behavior similar to that of andalusite and sillimanite. Cyanite is, however, more resistive to the action of chemical agents. Hence, Groth considers it a basic metasilicate, $(\text{AlO})_2\text{SiO}_3$, while andalusite and sillimanite are interpreted as being basic orthosilicates with the general formula $\text{Al}(\text{AlO})\text{SiO}_4$.

Cyanite is a characteristic mineral of rocks which have been subjected to intense regional metamorphism. Hence, it is found commonly in gneisses and mica schists, especially paragonite schist. It never occurs in eruptive rocks and only rarely in those which are the result of contact metamorphism. The usual associates are garnet, staurolite, corundum, rutile, and lazulite.

The principal localities are Monte Campione, St. Gothard district, Switzerland; various places in Tyrol, Sweden, and Brazil. In the United States it is found at Chesterfield, Mass.; Litchfield and Washington, Conn.; Thetford, Vt.; Chester and Delaware counties, Pa.; Buckingham, Va.; Gaston, Rutherford, and Yancey counties, N. C.

It is sometimes used as a gem.

TOPAZ, $\text{Al}_2(\text{F,OH})_2\text{SiO}_4$.

Orthorhombic, bipyramidal class. $a : b : c = 0.5281 : 1 : 0.47697$. Generally in highly modified, prismatic crystals. Over 140 different forms have been observed. Figures 108a, 108b, and 108c show common combinations consisting of the unit and brachyprisms m and l , unit and modified bipyramids u , o , and i , basal pinacoid c , brachypinacoid b , macrodome d , and the modified brachydomes f and y . The prism faces are often striated vertically. Crystals usually have but one end well developed. Sometimes massive, also coarse or fine granular.

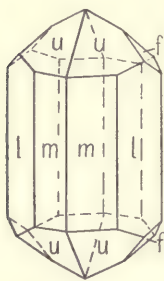


FIG. 108a

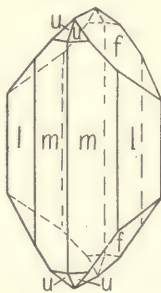


FIG. 108b

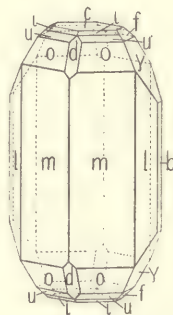


FIG. 108c

Very perfect basal cleavage, often indicated by well defined cracks. Conchoidal to uneven fracture. Hardness 8. Specific gravity 3.4 to 3.6. Vitreous luster. Usually transparent, but may be translucent or opaque. Colorless, wine yellow, grayish, violet, reddish, or bluish. Some of the colored varieties fade on exposure to daylight. The yellow color of many of the topaz crystals from Brazil changes to pale rose-pink when subject to a low, red heat. The biaxial interference figure can be seen in cleavage fragments.

$\text{Al}_2(\text{F,OH})_2\text{SiO}_4$. The percentages of fluorine and hydroxyl vary greatly. Fluorine usually predominates and in the varieties containing a small amount the following approximate proportion generally obtains, $\text{F} : \text{OH} = 3 : 1$; the composition of the varieties containing the highest percentage may be expressed approximately by $\text{Al}_2\text{F}_2\text{SiO}_4$. With an increase of the hydroxyl the a axis increases, while the c axis decreases in length. Often contains considerable amounts of microscopic, liquid and gaseous inclusions, especially liquid carbon dioxide. Infusible and, as indicated above, the colors may change. Treated with cobalt nitrate solution it turns blue. Slightly acted upon by sulphuric acid. Yields hydrofluoric acid when fused with salt

of phosphorous. Although it resists the action of weathering agencies to a high degree, it sometimes alters to talc and kaolinite.

Topaz is a characteristic mineral of the pneumatolytic process of formation and, hence, is generally associated with cassiterite, tourmaline, quartz, fluorite, apatite, beryl, mica, scheelite, wolframite, and zircon. It occurs in veins, crevices, and pegmatite dikes in highly acid igneous rocks such as granites, rhyolites, gneisses, and mica schists.

Excellent crystals are found at Schneckenstein, Zinnwald, and Altenberg, Saxony; various places in the Ural Mts., Siberia, Scotland, Ireland, Sweden, Japan, Australia, Mexico, and in Minas Geraes, Brazil. It is often found in the sands and gravels of the streams of Ceylon, Brazil, and the Ural Mts.

In the United States fine specimens are found in the Thomas Range, Utah, about 40 miles north of Sevier Lake; also at Nathrop, Colo.; Ramona district, San Diego County, Cal.; Trumbull, Conn.; Huntington and Middletown, Conn.; North Chatham, N. H.; Stoneham, Me.

Clear and transparent crystals are used as gems.

DATOLITE GROUP

This group embraces basic orthosilicates containing calcium, iron, beryllium, aluminium, boron, and the elements of the yttrium group. All members of the group crystallize in the monoclinic system.

	<i>a</i>	:	<i>b</i>	:	<i>c</i>		β
Datolite , $\text{Ca}(\text{B.OH})\text{SiO}_4$,	0.6348	:	1	:	1.2657,		$90^\circ 9'$.
EUCLASE , $\text{Be}(\text{Al.OH})\text{SiO}_4$,	0.6474	:	1	:	1.3330,		$100^\circ 16'$.
HOMILITE , $\text{Fe}[\text{Ca}(\text{B.O})\text{SiO}_4]_2$,	0.6249	:	1	:	1.2824,		$90^\circ 39'$.
Gadolinite , $\text{Fe}[\text{Be}(\text{Y.O})\text{SiO}_4]_2$,	0.6273	:	1	:	1.3215,		$90^\circ 33\frac{1}{2}'$.

If the formulas are written as suggested by Bauer, the similarity in comparison is more apparent.

Datolite, $\text{H}_2\text{Ca}_2\text{B}_2\text{Si}_2\text{O}_{10}$,
EUCLASE, $\text{H}_2\text{Be}_2\text{Al}_2\text{Si}_2\text{O}_{10}$,
HOMILITE, $\text{FeCa}_2\text{B}_2\text{Si}_2\text{O}_{10}$,
Gadolinite, $\text{FeBe}_2\text{Y}_2\text{Si}_2\text{O}_{10}$.

It will be observed that the formulas given for datolite and euclase in the first table have been doubled.

Datolite, Datholite, Datolithe, $\text{Ca}(\text{B.OH})\text{SiO}_4$.

Monoclinic, prismatic class. $a : b : c = 0.6348 : 1 : 1.2657$, $\beta = 90^\circ 9'$. Usually in excellent, highly modified crystals. Over 100 different forms have been observed. Prismatic and pyramidal, Figures 109 and 110, as well as tabular habits are rather common. *Botryolite* is a compact, fine fibrous variety with globular or botryoidal surfaces. In the Lake Superior copper district it occurs in compact, dull, granular masses, resembling wedgewood ware or unglazed porcelain.

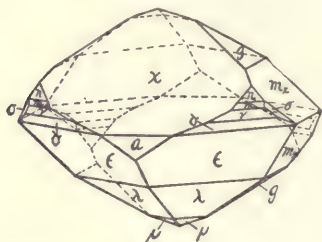


FIG. 109

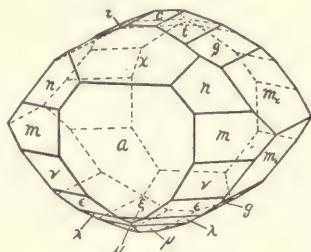


FIG. 110

No cleavage. Conchoidal to uneven fracture. Brittle. White streak. Hardness 5 to 5.5. Specific gravity 2.9 to 3. Vitreous to dull luster, sometimes resinous on fracture surfaces. Transparent to translucent, rarely opaque. Colorless, white, greenish, yellowish, various shades of red, violet, and brown.

$\text{Ca}(\text{B.OH})\text{SiO}_4$. Crystals are usually very pure. Colors the flame green and fuses with intumescence to a clear glass. Yields water in a closed tube. Gelatinizes when treated with hydrochloric acid.

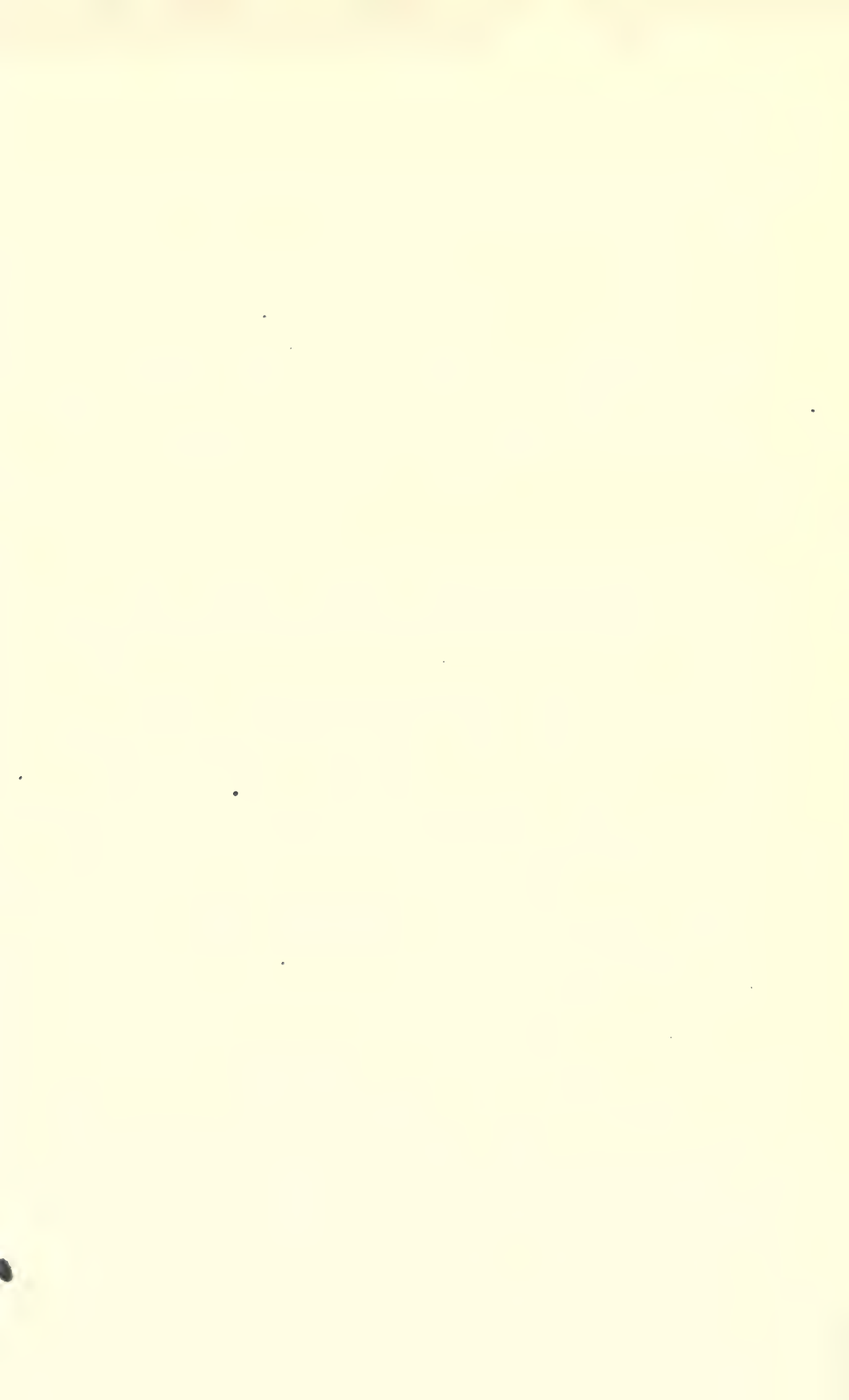
Datolite is a secondary mineral and its occurrences are very similar to those of the zeolites. It is generally found in cracks and cavities in basic igneous rocks, such as diorite, diabase, melaphyre, gabbro, and serpentine. The common associates are calcite, prehnite, native copper, magnetite, and the zeolites.

Some localities are the Kilpatrick Hills, Scotland; Arendal and Utö, Norway; Andreasberg, Hartz Mts., Tyrol; Bergen Hill, N. J.; Westfield and Deerfield, Mass.; Hartford, Conn.; and in the Lake Superior copper district in excellent crystals and porcelain-like masses.

Recently the massive, compact varieties of the copper district of Northern Michigan have been cut and polished for gem purposes.

EUCLASE, $\text{Be}(\text{Al.OH})\text{SiO}_4$.

Monoclinic, prismatic class. $a : b : c = 0.6474 : 1 : 1.3330$, $\beta = 100^\circ 16'$. Occurs only in prismatic crystals, generally very complex. The prism faces are striated vertically. Excellent clinopinacoidal cleavage. Conchoidal fracture. High vitreous lustre. Transparent, rarely translucent. Hardness 7 to 8. Specific gravity 3.05 to 3.11.



Colorless to blue or green. Barely fuses before the blowpipe. Not acted upon by acids. Occurs associated with chrysoberyl and topaz in the gold-bearing sands of the Sanarka river, Ural Mts.; and in quartz veins in chlorite schists at Boa Vista, Minas Geraes, Brazil.

Euclase is cut for gems.

HOMILITE, $\text{Fe}[\text{Ca}(\text{B.O})\text{SiO}_4]_2$.

Monoclinic, prismatic class. $a : b : c = 0.6249 : 1 : 1.2824$, $\beta = 90^\circ 39'$. Crystals usually possess an octahedral habit. No distinct cleavage. Subconchoidal fracture. Brownish black to black in color. Grayish white streak. Generally opaque, in thin fragments translucent. Greasy vitreous luster. Hardness 5 to 5.5. Specific gravity 3.28 to 3.4. Fuses to a black glass. Easily and completely soluble in hydrochloric acid. Occurs disseminated in the nepheline syenite of the Island of Stokö and vicinity, Norway.

Gadolinite, $\text{Fe}[\text{Be}(\text{Y.O})\text{SiO}_4]_2$.

Monoclinic, prismatic class. $a : b : c = 0.6273 : 1 : 1.3215$, $\beta = 90^\circ 33\frac{1}{2}'$. Crystals, which are very rare, are usually rough and of a prismatic habit. The common forms are the unit prism, basal pinacoid, unit clinodome, and the positive and negative hemipyramids. Occurs more commonly in masses.

No cleavage. Conchoidal fracture. Pitch to greenish black or brown in color. Opaque, thin fragments are translucent and appear green to brown in transmitted light. Greenish gray streak. Hardness 6 to 7. Specific gravity 4 to 4.5. Vitreous to greasy luster.

$\text{Fe}[\text{Be}(\text{Y.O})\text{SiO}_4]_2$. Contains as high as 16% of the oxide of cerium and from 23 to 51% of the oxides of the yttrium group; also small amounts of other elements not indicated in the formula. Analyses are rather complex. When heated, it glows without fusing. Gelatinizes with hydrochloric acid.

Gadolinite is not a common mineral. It has been found at Hitterö, Norway; Falun and Ytterby, Sweden; and in large nodular masses and crystals, associated with allanite, fergusonite, fluorite, molybdenite, and other rare minerals, in a pegmatite vein at Barringer Hill, Llano County, Texas.

It is a source of the oxides of some of the rare earths.

TOURMALINE, $\text{M}'_3\text{Al}_3(\text{B.OH})_2\text{Si}_4\text{O}_{19}$.

Hexagonal, ditrigonal pyramidal class. $a : c = 1 : 0.4474$. Often in large prismatic crystals with vertical striations. Short, thick crystals are also common. Hemimorphic development is usually very pronounced. The

blunter pole is the analogue, the more acute the antilogue. Figures 111 and 112 show a characteristic combination consisting of the negative trigonal prism l , the hexagonal prism of the second order s , the unit trigonal pyramids p and P , the upper negative trigonal pyramid o , the modified positive upper ditrigonal pyramid t , and the lower positive modified trigonal pyramid n . On account of the occurrence of the trigonal prism, cross-sections

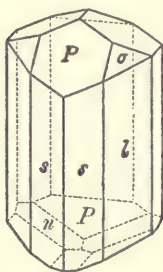


FIG. 111

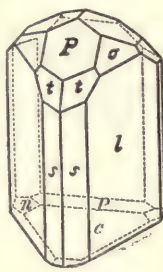


FIG. 112

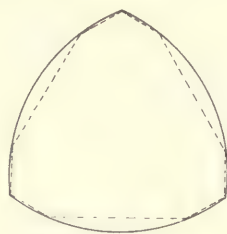


FIG. 113

tions of tourmaline generally show a spherical triangular outline. This is shown by figure 113. When the lateral development of the crystal has been ideal the cross-section is equilateral, otherwise the spherical triangle may be isosceles or scalene. Twins are very rare. Occurs also in compact, disseminated masses, and in radially divergent aggregates—the so-called *tourmaline suns*. Also in loose crystals in secondary deposits.

No well defined cleavage. Subconchoidal to uneven fracture. Hardness 7 to 7.5. Specific gravity 2.94 to 3.24. Vitreous luster, on fracture surfaces somewhat resinous. Usually pitch black, brown, gray, yellow, green, or red in color. More rarely colorless or white. Zonal distribution of color is often very marked. Transparent to opaque. The pitch black varieties are commonly opaque. Strong negative double refraction. $\omega_r = 1.643$, $\epsilon_r = 1.623$. Strongly dichroic. The absorption of the ordinary ray vibrating perpendicular to the vertical axis is much stronger than that of the extraordinary. Often used in the production of polarized light, for example, in tourmaline tongs. The red, green, or brown varieties are more strongly pyro-electric than the black.

$M'_9Al_3(B.OH)_2Si_4O_{19}$. On account of the very complex chemical composition, many formulas have been assigned to tourmaline. The formula given above is the one suggested by Penfield and Foote. M indicates the alkali metals—sodium, potassium, or lithium,—magnesium, or iron. The hydroxyl is often replaced by fluorine. Some tourmalines contain small amounts of titanium or chromium. Four varieties, based upon the chemical composition, may be differentiated, namely, (1) *Lithium*, (2) *Iron*, (3) *Iron-magnesium*, and (4) *Magnesium tourmalines*. Powdered tourmaline, when

fused with a paste of potassium bisulphate and fluorite, imparts a momentary green color to the flame indicating the presence of boric acid. Fusibility varies greatly. Insoluble in acids. Gelatinizes after fusion or strong ignition. Although rather resistive to weathering agencies, it frequently alters to muscovite, biotite, or chlorite.

According to color and occurrences several varieties are commonly differentiated.

(1) *Ordinary*. Crystals of various colors. Black is the most common variety.

(2) *Rubellite*. Red, rose red, and ruby red varieties. Sometimes often called *siberite*.

(3) *Indicolite or Indigolite*. Bluish varieties.

(4) *Achroite*. Colorless variety from the Island of Elba.

(5) *Schorl*. This includes the common black varieties.

Tourmaline is a very characteristic mineral of pegmatite dikes associated with intrusions of granite. It is the result of the pneumatolytic process of formation, as is evidenced by the presence of fluorine, hydroxyl, and boron. It is rather common in contact metamorphic rocks, such as gneisses, schists, and crystalline limestones and dolomites. Its occurrence is usually indicative of nearness to the contact. Some of the common associates are quartz, cassiterite, fluorite, apatite, topaz, and various copper and iron ores.

Occurs in Cornwall, England; Arendal, Norway; Ural Mts.; Island of Elba; Minas Geraes, Brazil; Burma.

Excellent crystals are found at Paris, Auburn, and Rumford, Me.; Had-dam Neck, Conn.; Goshen, Mass.; Gouverneur, DeKalb, and Pierrepont, N. Y.; Grafton, N. H.; San Diego County, Cal.; also in various places in Canada.

Stones of good colors are cut for gem purposes. On account of its strong absorption it is used in making *tourmaline tongs*, a simple instrument for producing polarized light.

LAWSONITE GROUP

The two minerals, lawsonite and carpholite, are placed here. Although their chemical composition is very similar, their crystallographic properties vary greatly.

	a	:	b	:	c
Lawsonite, $\text{Ca}(\text{Al}_2\text{OH})_2(\text{SiO}_3)_2$.	Orthorhombic,	0.6652	:	1	: 0.7385
CARPHOLITE, $\text{Mn}(\text{Al}_2\text{OH})_2(\text{SiO}_3)_2$.	Monoclinic,		?		

Lawsonite is sometimes considered an orthosilicate.

Lawsonite, $\text{Ca}(\text{Al}_2\text{OH})_2(\text{SiO}_3)_2$.

Orthorhombic, bipyramidal class. $a : b : c = 0.6652 : 1 : 0.7385$. Thick, tabular and prismatic crystals. Prism angle is $112^\circ 44'$. Six sided cross section. Perfect basal and brachypinacoidal cleavages. Hardness 8 to 8.5. Specific gravity 3.1. Vitreous to greasy luster. Colorless, pale or grayish blue. Often multi-colored. Fuses easily to a black enamel, which gelatinizes readily with hydrochloric acid.

Occurs in crystals in schists in Martin County, Cal.; also on the Island of Corsica and in New Caledonia.

CARPHOLITE, $\text{Mn}(\text{Al}_2\text{OH})_2(\text{SiO}_3)_2$.

Monoclinic. Occurs only in fine hair-like crystals, often in radial aggregates. Vitreous to silky luster. Translucent. Straw, wax, or greenish yellow in color. Colorless streak. Hardness 5 to 5.5. Specific gravity 2.9. Fuses with intumescence. Only slightly acted upon by acids. Occurs with blue fluorite in the tin ore deposits of Schlaggenwald, Bohemia; also at Wippia, Hartz Mts.

Ilvaite, Lievrite, $\text{CaFe}_2(\text{Fe.OH})(\text{SiO}_4)_2$.

Orthorhombic, bipyramidal class. $a : b : c = 0.6665 : 1 : 0.4427$. Columnar to needle-like crystals with vertical striations on the prism faces. The prism angle is $112^\circ 38'$. Occurs also in compact masses with a radial fibrous structure, and in granular aggregates.

Distinct basal and brachypinacoidal cleavages. Uneven to subconchoidal fracture. Vitreous luster when fresh, otherwise usually submetallic. Opaque to slightly translucent. Hardness 5 to 6. Specific gravity 3.9 to 4.1. Black greenish, or brownish in color and streak. The surface is often covered with an ocher-yellow alteration product.

$\text{CaFe}_2(\text{Fe.OH})(\text{SiO}_4)_2$. Manganese may replace some of the bivalent iron. Fuses easily and yields a magnetic globule. Gelatinizes with hydrochloric acid. Usually the result of contact metamorphism. Occurs generally with iron ore deposits, thus, on the Island of Elba; Nassau, Germany; Silesia; Cumberland, R. I.; Somerville, Mass.; also in Greenland and Iceland.

HUMITE GROUP

Chemically and crystallographically this is a most interesting group of minerals, there being uniform chemical and crystallographic differences between the successive members of the series. Proectite possesses the simplest chemical composition. The addition of one molecule of Mg_2SiO_4 gives the composition of chondrodite, the addition of two molecules that of humite, while the addition of three molecules yields the composition of clinohumite.

	a	b	c	β
PROLECTITE, $[\text{Mg}(\text{F},\text{OH})]_2 \text{Mg}(\text{SiO}_4)$, Monoclinic, 1.0803	1	3	$\times 0.6287$	90°
Chondrodite, $[\text{Mg}(\text{F},\text{OH})]_2 \text{Mg}_3(\text{SiO}_4)_2$, Monoclinic, 1.0863	1	5	$\times 0.6289$	90°
HUMITE, $[\text{Mg}(\text{F},\text{OH})]_2 \text{Mg}_5(\text{SiO}_4)_3$, Orthorhombic, 1.0802	1	7	$\times 0.6291$	—
CLINOHUMITE, $[\text{Mg}(\text{F},\text{OH})]_2 \text{Mg}_7(\text{SiO}_4)_4$, Monoclinic, 1.0803	1	9	$\times 0.6288$	90°

Although all of the members do not crystallize in the monoclinic system, the elements of crystallization show an interesting relationship. While the a and b axes are practically of the same length, it will be observed that the c axis increases uniformly and in fact in a definite ratio. This ratio, 3 : 5 : 7 : 9, also holds good for the number of atoms of magnesium in the successive members of the series. The value of the angle β is in all cases practically 90° . Only chondrodite is of sufficient importance to warrant a detailed description.

PROLECTITE, $[\text{Mg}(\text{F},\text{OH})]_2 \text{MgSiO}_4$.

Monoclinic, prismatic class. The elements of crystallization, given above, seem to indicate that prolectite is the first member of the humite group. The mineral is extremely rare and has not as yet been analyzed. Has been found in the Ko mine, Nordmarken, Sweden.

Chondrodite, $[\text{Mg}(\text{F},\text{OH})]_2 \text{Mg}_3(\text{SiO}_4)_2$,

Monoclinic, prismatic class. $a : b : c = 1.0863 : 1 : 3.1447$, $\beta = 90^\circ$. Occurs in small, highly modified, pseudo-orthorhombic crystals, also in round grains or lumps, and granular aggregates.

Distinct basal cleavage. Uneven to conchoidal fracture. Vitreous to resinous luster. Translucent to opaque. Brittle. White streak. Brown, light to dark yellow, and hyacinth to garnet red in color. Hardness 6 to 6.5. Specific gravity 3.1 to 3.25.

$[\text{Mg}(\text{F},\text{OH})]_2 \text{Mg}_3(\text{SiO}_4)_2$. Some of the magnesium may be replaced by bivalent iron. Infusible. Reacts for fluorine.

Chondrodite is a typical contact metamorphic mineral. It occurs commonly in crystalline limestones and dolomites, associated with spinel, vesuvianite, magnetite, pyroxene, and phlogopite. Alters to serpentine. Some important localities are Pargas, Finland; Aeker and Gulsjoe, Sweden; Sparta, N. J.; Monroe, and Tilly Foster mine, near Brewster, N. Y.; also in Burma and on Mt. Vesuvius.

HUMITE, $[\text{Mg}(\text{F},\text{OH})]_2 \text{Mg}_5(\text{SiO}_4)_3$.

Orthorhombic, bipyramidal class. Highly complex crystals, often twinned. Yellow, reddish, and brownish in color. Vitreous luster. Hardness 6. Specific gravity 3.1 to 3.2. Transparent to translucent. Occurs in Sweden; Andalusia, Spain; Mt. Vesuvius; Tilly Foster mine, N. Y.

CLINOHUMITE, $[\text{Mg}(\text{F.OH})]_2 \text{Mg}_7(\text{SiO}_4)_4$.

Monoclinic, prismatic class. Highly complex crystals. Very similar to and more common than humite. Found on Mt. Vesuvius; Andalusia, Spain; Tilley Foster mine, N. Y.

HELVITE GROUP

The members of this group are orthosilicates containing sulphur, which may be easily liberated as hydrogen sulphide by the action of hydrochloric acid. The two members of the group crystallize in the cubic system.

HELVITE, $(\text{Mn,Be,Fe})_7\text{S}(\text{SiO}_4)_3$. Hextetrahedral Class

DANALITE, $(\text{Fe,Zn,Be,Mn})_7\text{S}(\text{SiO}_4)_3$. Hextetrahedral Class

Danalite is sometimes considered a zinciferous variety of helvite.

HELVITE, $(\text{Mn,Be,Fe})_7\text{S}(\text{SiO}_4)_3$.

Cubic, hextetrahedral class. Small tetrahedral crystals, oftentimes disseminated. Occurs also in spherical aggregates.

Indistinct octahedral cleavage. Uneven fracture. Brittle. Hardness 6 to 6.5. Specific gravity 3.1 to 3.3. Resinous to vitreous luster. Translucent. Sulphur, honey, or brownish yellow in color; also siskin green and reddish brown. Colorless streak. Pyroelectric.

$(\text{Mn,Be,Fe})_7\text{S}(\text{SiO}_4)_3$. Somewhat similar in composition to the garnet group of minerals, page 208. Fuses with intumescence to a yellowish brown opaque bead. Yields hydrogen sulphide and gelatinizes when treated with hydrochloric acid. Reacts for manganese.

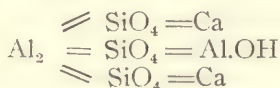
Helvite is often associated with iron, zinc, and lead ores. Occurs at Schwarzenberg and Breitenbrunn, Saxony; Kapnik, Hungary; Ilmen Mts., Russia; Amelia Court House, Amelia County, Va.

DANALITE, $(\text{Fe,Zn,Be,Mn})_7\text{S}(\text{SiO}_4)_3$.

Cubic, hextetrahedral class. Crystals are apparently holohedral and usually consist of a combination of the octahedron and the rhombic dodecahedron. Occurs mostly massive and disseminated. No distinct cleavage. Subconchoidal to uneven fracture. Brittle. Hardness 5.5 to 6. Specific gravity 3.43. Resinous vitreous luster. Translucent. Flesh red to gray in color. Edges fuse easily. Reacts for zinc. Yields hydrogen sulphide when treated with hydrochloric acid. Occurs in granite at Cape Ann and Gloucester, Mass.; with iron ores at Bartlett, N. H.; El Paso County, Colo.

EPIDOTE GROUP

This group embraces minerals of the following general composition



in which a portion of the aluminium may be replaced by iron, manganese, or cerium. The group is dimorphous.

ORTHORHOMBIC SERIES

$a \quad : \quad b \quad : \quad c$

Zoisite, $\text{Ca}_2\text{Al}_2(\text{Al.OH})(\text{SiO}_4)_3$, Bipyramidal Class 2.9158 : 1 : 1.7900

MONOCLINIC SERIES

$a \quad : \quad b \quad : \quad c \quad \quad \beta$

CLINOZOISITE, $\text{Ca}_2\text{Al}_2(\text{Al.OH})(\text{SiO}_4)_3$.
Prismatic Class 2.8914 : 1 : 1.8057, 98° 57'

EPIDOTE, $\text{Ca}_2(\text{Al,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$,
Prismatic Class 2.8914 : 1 : 1.8057, 98° 57'

PIEMONTE, $\text{Ca}_2(\text{Mn,Al})_2(\text{Al.OH})(\text{SiO}_4)_3$.
Prismatic Class 2.9451 : 1 : 1.8362, 98° 52'

Orthite, $\text{Ca}_2(\text{Al,Ce,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$,
Prismatic Class 2.8473 : 1 : 1.7684, 99° 14'

Although the elements of crystallization given in the tabulation show the close similarity of the members of the group, they are not used in the subsequent descriptions of the minerals. The chemical and crystallographic properties of zoisite and epidote are very much alike. In clinozoisite a small amount of aluminium has been replaced by iron, its properties being almost identical with those of epidote, and it will therefore not be described.

Zoisite, $\text{Ca}_2\text{Al}_2(\text{Al.OH})(\text{SiO}_4)_3$.

Orthorhombic, bipyramidal class. $a : b : c = 0.6196 : 1 : 0.3429$. Prismatic crystals, often disseminated. Deep vertical striations on the faces of the unit prism, horizontal striations on the brachypinacoid. Crystals are generally bent and without good terminations. Columnar, broad bladed, or fibrous aggregates are more common than isolated crystals.

Perfect brachypinacoidal cleavage. Uneven to subconchoidal fracture. Hardness 6 to 6.5. Specific gravity 3.25 to 3.37. Brittle. Vitreous luster, more or less pearly on cleavage surfaces. Commonly ash gray in color, also yellow, greenish gray, brownish, or apple green; more rarely rose red. *Thulite* is a rose red variety occurring in Tellemarken and at Arendal, Norway,

and at Travesella, Piedmont. Uncolored streak. Transparent to subtranslucent. Strongly pleochroic. Zoisite resulting from the alteration of feldspar is termed *saussurite*. It is sometimes mixed with actinolite, chlorite, and feldspar.

$\text{Ca}_2\text{Al}_2(\text{Al.OH})(\text{SiO}_4)_3$. Some ferric oxide may replace Al_2O_3 . Fuses with intumescence to a transparent bead. Not attacked by acids, but after ignition, gelatinizes with hydrochloric acid.

Occurs principally in crystalline schists, such as eclogites, amphibolites, glaucophane schists, and metamorphosed gabbros. Zoisite is often the result of metamorphism. The principal localities are Rauris, Salzburg; Saualpe, Carinthia; Tyrol; Fichtelgebirge; Marschendorf, Moravia; Island of Syra; the Coast Range, California; Ducktown, Tenn.; Chesterfield, Mass.; and Uniontown, Pa.

EPIDOTE, Pistacite, $\text{Ca}_2(\text{Al,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$.

Monoclinic, prismatic class. $a : b : c = 1.5787 : 1 : 1.8036$, $\beta = 64^\circ 37'$. Excellent, highly modified crystals. Over 200 forms have been observed. Usually prismatic and deeply striated parallel to the b axis. The

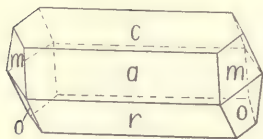


FIG. 114

common forms are the basal and orthopinacoids c and a , hemiorthodome r , unit prism m , and the unit hemipyramid o , figure 114. Polysynthetic twins with the twinning plane parallel to the orthopinacoid are rather common; more rarely the basal pinacoid acts as twinning plane. Aside from crystals, divergent or parallel fibrous and columnar aggregates, and coarse or fine grained masses are common; sometimes also in spherical or angular grains.

Perfect basal and imperfect orthopinacoidal cleavages. Splintery, uneven, or subconchoidal fracture. Brittle. Hardness 6 to 7. Specific gravity 3.25 to 3.5. Vitreous to resinous luster. Rarely transparent, usually translucent to opaque. Crystals are generally dark green, bluish green, or blackish green; aggregates are lighter in color—pistachio-green, yellowish green, and more rarely red or colorless. Uncolored to grayish streak. Strongly pleochroic.

$\text{Ca}_2(\text{Al,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$. The percentages of the oxides of calcium, aluminium, iron, and silicon vary considerably as follows, CaO 23 to 24%, Al_2O_3 20 to 30%, Fe_2O_3 8 to 16%, and SiO_2 35 to 37%. As indicated above, *clinzoisite* is a variety containing little or no iron. Loses water when strongly ignited. Fuses with intumescence to a magnetic slag. After ignition gelatinizes with hydrochloric acid.

Epidote is a very common mineral and occurs in four ways. (1) It is a typical metamorphic mineral and is generally associated with garnet, vesuvianite, fassaite, hornblende, hematite, and magnetite. Sometimes it

occurs very extensively, forming *epidote rocks and schists*. (2) It is also a common decomposition product of minerals and igneous rocks containing a considerable amount of the oxides of aluminium and calcium, such as feldspar, hornblende, scapolite, pyroxenes, biotite, and the like. (3) Epidote is often found as sandy grains in secondary deposits. (4) As a pseudomorph after scapolite, garnet, augite, and hornblende.

Beautiful crystals are found in many localities, some of the more important of which are the following: Zillerthal, Fassathal, and Untersulzbachthal, Tyrol; Travesella, Piedmont; Island of Elba; Dauphine, France; Arendal, Norway; Ural Mts.; also various places in New Hampshire, New York, Massachusetts, Connecticut, New Jersey, Colorado, and Virginia. It is a very common associate of native copper in the Lake Superior copper district.

Clear, transparent, dark green varieties are sometimes used for gem purposes.

PIEMONTE, Manganiferous Epidote, $\text{Ca}_2(\text{Mn,Al})_2(\text{Al.OH})(\text{SiO}_4)_3$.

Monoclinic, prismatic class. $a : b : c = 1.61 : 1 : 1.833$, $\beta = 115^\circ 21'$. Crystallographically very similar to epidote. Commonly in crystalline, columnar and radial aggregates, more or less indistinct. Perfect basal cleavage. Hardness 6.5. Specific gravity 3.4. Vitreous luster, especially good on the basal pinacoid. Transparent only in thin sections or fragments. Reddish brown or black in color. Cherry red streak. Strongly pleochroic.

May be considered a manganiferous variety of epidote, containing from 6 to 10% of MnO . After ignition gelatinizes with hydrochloric acid.

Occurs at St. Marcel, Piedmont, Italy; Isle de Groix, Brittany; Japan; England; South Mountain, Pa.

Orthite, Allanite, $\text{Ca}_2(\text{Al,Ce,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$.

Monoclinic, prismatic class. $a : b : c = 1.5507 : 1 : 1.7684$, $\beta = 115^\circ 1'$. Crystals, which are not very common, are either tabular parallel to the orthopinacoid or long prismatic parallel to the b axis. Usually in massive, granular, or bladed aggregates; also as disseminated grains.

Distinct basal and orthopinacoidal cleavages, rarely observed. Uneven to conchoidal fracture. Hardness 5.5 to 6. Specific gravity 3 to 4. Greasy, submetallic luster. Opaque, translucent in thin splinters. Pitch black in color, sometimes brownish or grayish. The black varieties are often coated with a rusty alteration crust. Greenish gray or brown streak.

$\text{Ca}_2(\text{Al,Ce,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$. The composition varies greatly. More or less decomposed varieties also contain didymium, lanthanum, yttrium, magnesium, and water. Those with much water contain less CaO . The amount of Ce_2O_3 varies between 1 and 28 per cent. Fuses readily with intumescence to a black magnetic glass. Gelatinizes with hydrochloric acid, not, however, if previously ignited.

Orthite occurs in small quantities in all kinds of igneous rocks, especially in granites and pegmatites; also in gneiss, mica schist, and amphibolite. Sometimes also in crystalline limestone.

CERITE, $H_4(Ca,Fe)_2Ce_6Si_6O_{26}$.

Orthorhombic, bipyramidal class. $a : b : c = 0.9988 : 1 : 0.8127$. Crystals are rare, prismatic. Usually compact and granular.

Brittle. Splintery fracture. Hardness 5.5. Specific gravity 4.95. Clove-brown, reddish gray to cherry red in color. Translucent to opaque. Grayish white streak.

$H_4(Ca,Fe)_2Ce_6Si_6O_{26}$. Infusible. Decomposed by hydrochloric acid. Hisinger and Berzelius discovered cerium in this mineral in 1803.

Occurs in gneiss, associated with biotite, hornblende, chalcocite, orthite, and bis-muthinite in the Bastnaes mine, Riddaryttan, Sweden.

VESUVIANITE, Idocrase, $Ca_6[Al(OH,F)]Al_2(SiO_4)_5$.

Tetragonal, ditetragonal bipyramidal class. $a : b : c = 1 : 0.5372$. Crystals are generally short and prismatic, rarely pyramidal or acicular. A usual combination consists of the unit prism m predominating, the prism of the second order a , the corresponding bipyramids o and p , and the basal pinacoid c , figure 115. Over 60 forms have been observed. No twin crystals have been recorded. Occurs also compact and granular, in aggregates with parallel and divergent striations, also in cryptocrystalline masses.

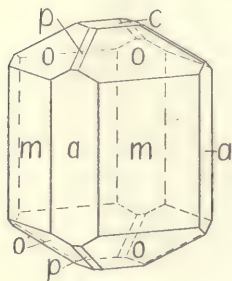


FIG. 115

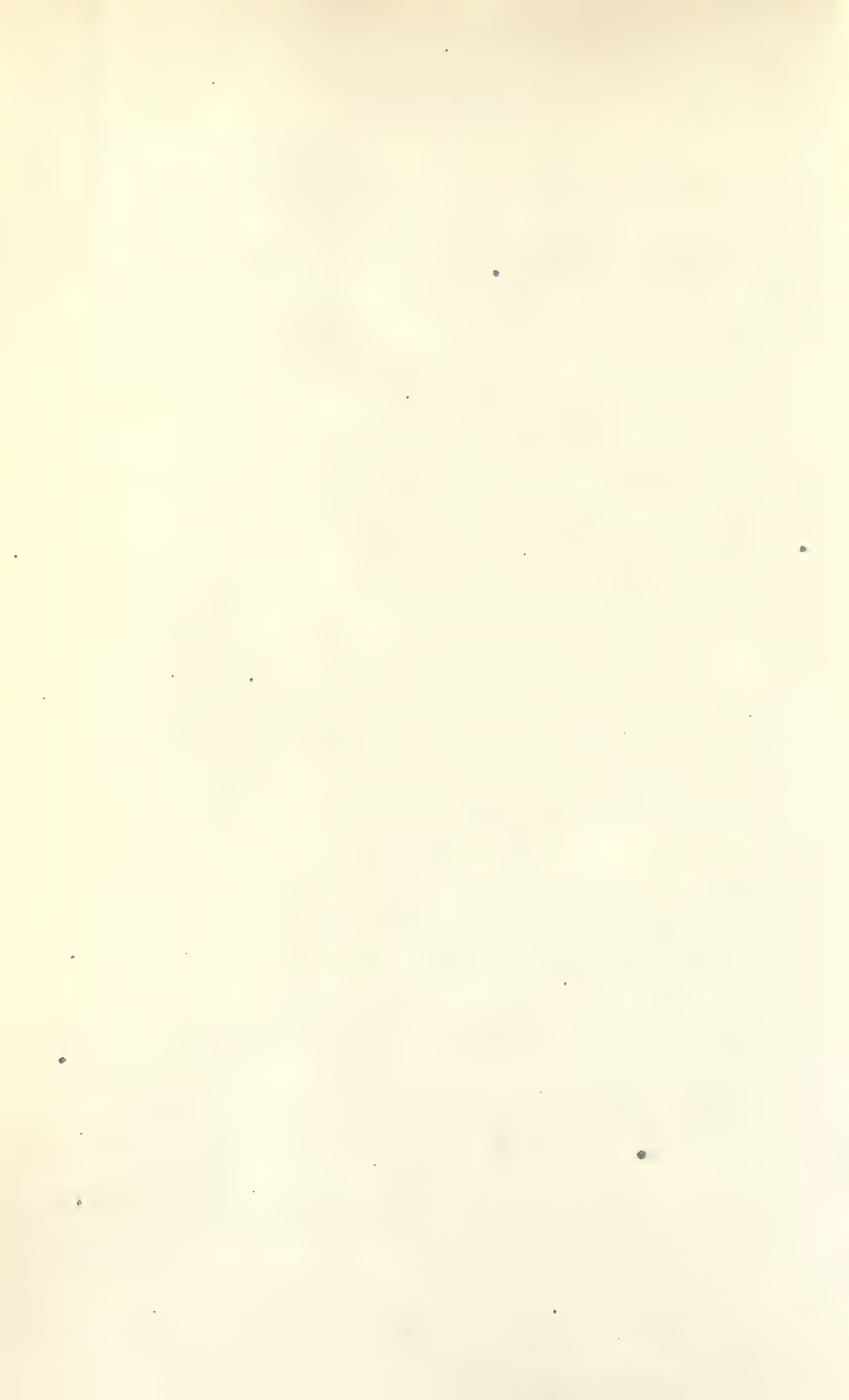
Imperfect basal and prismatic cleavages. Uneven and subconchoidal fractures. Hardness 6.5. Specific gravity 3.34 to 3.45. Vitreous luster, greasy on fracture surfaces. Occurs in many shades of yellow, green, and brown; sometimes almost black; rarely blue. Sometimes transparent, usually translucent. Somewhat pleochroic.

$Ca_6[Al(OH,F)]Al_2(SiO_4)_5$. The composition is very complex and varies somewhat. Titanium may replace the silicon, boron the aluminium, and ferric oxide the aluminium oxide, and calcium may be replaced by varying amounts of magnesium, iron, manganese, sodium, potassium, or lithium. Fuses with intumescence to a greenish or brownish glass. After ignition, it decomposes easily with acids.

Vesuvianite is a mineral typical of contact metamorphism. It is found commonly in crystalline limestones, associated with garnet, pyroxene, tourmaline, chondrodite, wollastonite, epidote, and the like. It may also occur in gneiss and other crystalline schists. Some of the more important localities are: Monzoni, Fassathal, Tyrol; Ala Valley, Piedmont; Eger, Hungary; Morelos, Mexico; Warren, N. H.; Newton, N. J.; Amity, N. Y.; Rumford, Me.; various places in Canada.

Clear and transparent, brown and green varieties are used for gem purposes.





OLIVINE-WILLEMITE GROUPS

The members of these groups are normal orthosilicates and conform to the general formula M''_2SiO_4 . M may be magnesium, iron, manganese, zinc, or beryllium. The olivine group crystallizes in the orthorhombic system, the members of the willemite group, with the exception of trimerite, belong to the hexagonal system.

OLIVINE GROUP

(ORTHORHOMBIC SYSTEM)

		a	:	b	:	c
MONTICELLITE, $CaMgSiO_4$.	Bipyramidal Class	0.4337	:	1	:	0.5757
GLAUCOCHROITE, $CaMnSiO_4$.	Bipyramidal Class	0.4400	:	1	:	0.5660
FORSTERITE, Mg_2SiO_4 .	Bipyramidal Class	0.4666	:	1	:	0.5868
OLIVINE , $(Mg,Fe)_2SiO_4$.	Bipyramidal Class	0.4657	:	1	:	0.5865
HORTONOLITE, $(Fe,Mg,Mn)_2SiO_4$.	Bipyramidal Class	0.4660	:	1	:	0.5800
FAYALITE, Fe_2SiO_4 .	Bipyramidal Class	0.4580	:	1	:	0.5793
KNEBELITE, $(Mn,Fe)_2SiO_4$.	Bipyramidal Class	0.4670	:	1	:	?
TEPHROITE, Mn_2SiO_4 .	Bipyramidal Class	0.4621	:	1	:	0.5914

WILLEMITE GROUP

(HEXAGONAL SYSTEM)

		a	:	c
TRIMERITE, $MnBeSiO_4$	Triclinic (Pseudo-hexagonal)	1	:	0.7233
Phenacite , Be_2SiO_4 .	Trigonal Rhombohedral Class	1	:	0.6611
Willemite , Zn_2SiO_4 .	Trigonal Rhombohedral Class	1	:	0.6695

Of the above minerals, olivine and willemite are by far the most important.

MONTICELLITE, $CaMgSiO_4$.

Orthorhombic, bipyramidal class. $a : b : c = 0.4337 : 1 : 0.5757$. Occurs in small crystals, also in grains and masses. Colorless, white, and yellowish white. Transparent to opaque. No cleavage. Hardness 5 to 6. Specific gravity 3.12 to 3.28. Fuses with difficulty. Soluble in hydrochloric acid, gelatinizes on evaporation. Alters to serpentine or fassite, a variety of augite. Occurs in limestone, the result of contact metamorphism. Thus, on Mt. Somma, Vesuvius; Monzoni district, Tyrol; Magnet Cove, Arkansas.

GLAUCOCHROITE, $CaMnSiO_4$, is a rare bluish green mineral occurring with garnet and axinite in the Franklin Furnace district, N. J.

FORSTERITE, Mg_2SiO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.4666 : 1 : 0.5858$. Small crystals, often highly complex. Sometimes as irregular, disseminated grains. Brachypinacoidal cleavage. Hardness 6 to 7. Specific gravity 3.19 to 3.33. Transparent to translucent. Colorless, white, gray, yellowish, or greenish. May alter to serpentine. Sometimes contains as much as 5% of Fe_2O_3 .

Occurs associated with spinel, augite, and serpentine. It is the result of contact metamorphism on limestone or dolomite. Has been found in the Ural Mts.; Snarum, Norway; Bolton, Mass.

OLIVINE, Chrysolite, Peridot, $(\text{Mg,Fe})_2\text{SiO}_4$.

Orthorhombic, bipyramidal class. $a : b : c = 0.4657 : 1 : 0.5865$. Crystals are prismatic or thick tabular. Not very common. They are usually comparatively simple. A usual combination consists of the unit and brachyprisms m and s , unit bipyramid o , brachy- and macro-domes d and q , and the brachypinacoid b , figure 116. Such crystals are somewhat chisel-like in development. There are three twinning laws, (1) unit brachyprisms m and s , unit bipyramid o , brachy- and (3) brachyprism ($2a : b : \infty c$). Occurs also in loose, rounded, and disseminated grains and granular aggregates.

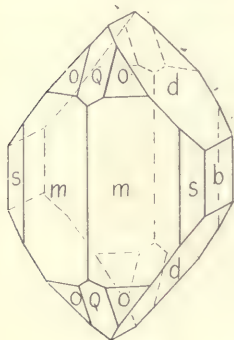


FIG. 116

Distinct brachy-, and rather poor macropinacoidal cleavages. Brittle. Hardness 6.5 to 7. Specific gravity 3.2 to 3.6, the varieties containing much iron approach 4. Vitreous luster, greasy on fracture surfaces. Transparent to translucent. Various shades of green, usually olive green, yellowish, brown, reddish, grayish, or colorless. Uncolored or slightly yellowish streak.

$(\text{Mg,Fe})_2\text{SiO}_4$. The composition varies greatly. According to Naumann-Zirkel olivine may be considered an isomorphous mixture of forsterite and fayalite, thus, $n(\text{Mg}_2\text{SiO}_4) + \text{Fe}_2\text{SiO}_4$. Titanium may replace some of the silicon. Nickel and calcium may also be present in small amounts. The ferruginous varieties are fusible with difficulty, the others infusible. Easily decomposed by acids, even acetic acid, forming gelatinous silica. Olivine weathers easily forming serpentine, limonite, hematite, magnesite, opal, and garnierite.

Olivine is an essential constituent of many basic igneous rocks. The associates are augite, hypersthene, spinel, plagioclase, feldspar, chromite, pyrope, and magnetite. It is also found in crystalline limestone, the result of metamorphism. The amphiboles, pyroxenes, and talc are typical associates of such occurrences.

Occurs on Mt. Vesuvius; Eifel, Auvergne; Norway; Sweden; Thetford, Vt.; Webster, N. C.; White Mountains, N. H.; Lancaster County, Pa.; New Mexico; Arizona; Canada; Brazil. Has been found in meteorites.

Transparent varieties are often used for gem purposes.

HORTONOLITE, $(\text{Fe}, \text{Mg}, \text{Mn})_2\text{SiO}_4$, yellowish green, or greenish or brownish black crystals and masses. Hardness 6 to 7. Specific gravity 3.91. Vitreous luster. Associated with magnetite and calcite, it occurs in the O'Neil mine, Orange county, N. Y.

FAYALITE, Fe_2SiO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.458 : 1 : 0.5793$. Crystals are generally tabular and when fresh possess a vitreous luster and a wine-yellow or olive-green color; when altered, the color is reddish with a metallic luster. If much magnetite is present the color may be black. Hardness 6 to 7. Specific gravity about 4. Usually contains manganese and magnesium. It is found on the Island of Fayal, Azores; Yellowstone Park; Rockport, Mass.

KNEBELITE, $(\text{Mn}, \text{Fe})_2\text{SiO}_4$, occurs in broad columnar aggregates or cleavage masses. Brachypinacoidal and prismatic cleavages. Greasy vitreous luster. Hardness 6 to 7. Specific gravity 3.93 to 4.17. Translucent. Grayish to black in color. Infusible. Occurs in the magnetite deposits of Dannemora, Sweden.

TEPHROITE, Mn_2SiO_4 .

Orthorhombic, bipyramidal class. $a : b : c = 0.4621 : 1 : 0.5914$. Crystals are very rare. Usually in crystalline masses with cleavages in three perpendicular directions. Conchoidal to splintery fracture. Vitreous luster, greasy on fracture surfaces. Translucent to transparent. Gray, brown, reddish, or rose-red in color. Hardness about 6. Specific gravity 3.95 to 4.12. Fuses with difficulty. Decomposed by hydrochloric acid.

A variety of tephroite from Sterling Hill, N. J., containing zinc, is called *roep-perite*.

Occurs with zincite, willemite, and franklinite at Franklin Furnace and Sparta, Sussex County, N. J.; Pajsberg and Langban, Sweden.

TRIMERITE, MnBeSiO_4 .

Triclinic, but on account of twinning, pseudo-hexagonal in development. Angles are very similar to those of phenacite. Crystals are usually thick tabular and prismatic. Distinct basal cleavage. Brittle. Hardness 6 to 7. Specific gravity 3.48. Vitreous luster. Transparent to translucent. Salmon pink to nearly colorless. Rare. Occurs with calcite in the Harstig mine, Wermland, Sweden.

Phenacite, Be_2SiO_4 .

Hexagonal, trigonal rhombohedral class. $a : c = 1 : 0.6611$. Crystals may be rhombohedral, prismatic, pyramidal, or lenticular in habit. Often highly modified, showing rhombohedrons of the third order. Supplementary twins are common.

Vitreous luster. Transparent to translucent. Indistinct cleavage parallel to the prism of the second order. Conchoidal fracture. Hardness 7 to 8. Specific gravity 2.97 to 3. Colorless, yellowish white, wine yellow, or pale rose red.

Be_2SiO_4 . Infusible and not attacked by acids. With borax, the powdered mineral fuses quite readily to a clear glass.

Occurs in pegmatites and some metamorphic rocks. It is commonly associated with emerald, chrysoberyl, apatite, quartz, beryl, amazonstone, and topaz. Very similar to quartz and topaz in appearance.

Phenacite is found in the Ural Mountains; Southern Norway; Brazil; Durango, Mexico; Stoneham, Me.; Pike's Peak, Topaz Butte, and Mount Antero, Colo.

Some varieties are used for gem purposes.

Willemite, Zn_2SiO_4 .

Hexagonal, trigonal rhombohedral class. $a : c = 1 : 0.6695$. Crystals are usually very small, although those containing manganese may be of considerable size. Long slender or thick prismatic habits are usual. Occurs also in compact, granular masses and in disseminated grains.

Distinct basal cleavage. Subconchoidal to uneven fracture. Hardness 5 to 6. Specific gravity 3.89 to 4.29. Greasy vitreous luster. Transparent to opaque. Colorless, yellowish, brown, reddish, green, yellowish green; rarely, blue or black. Uncolored streak.

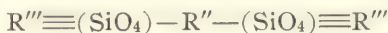
Zn_2SiO_4 . Manganese and iron may replace some of the zinc. *Troostite* is a manganiferous variety from the Franklin Furnace district, N. J. Fuses with difficulty. Reacts for zinc, often also for manganese. Gelatinizes with hydrochloric acid. Sometimes occurs pseudomorphous after calamine.

The usual associates are franklinite, zincite, rhodonite, and calcite. The most important locality is Franklin Furnace and vicinity, Sussex County, N. J., where it occurs in large quantities. It is found also at Altenberg, near Aachen, Germany; Musartut, Greenland; Merritt Mine, Socorro County, N. M.

It is an important ore of zinc.

DANBURITE GROUP

This group contains orthosilicates of the following general composition:



The bivalent metal is calcium, while the trivalent element is either boron or aluminium. They crystallize in the orthorhombic system.

	a	b	c
Danburite, $\text{CaB}_2(\text{SiO}_4)_2$.	0.5445	1	0.4808
BARSOWITE, $\text{CaAl}_2(\text{SiO}_4)_2$.		?	

These minerals are not very common.



Danburite, $\text{CaB}_2(\text{SiO}_4)_2$.

Orthorhombic, bipyramidal class. $a : b : c = 0.5445 : 1 : 0.4808$. Crystals are usually prismatic in habit, resembling topaz. The development varies greatly with the locality. Sometimes rather complex. Over 35 forms have been observed. Occurs also in indistinct crystals and disseminated masses.

Indistinct basal cleavage. Uneven to conchoidal fracture. Vitreous luster, at times somewhat greasy. Hardness 7 to 7.5. Specific gravity 2.95 to 3.02. When fresh and pure, it is transparent, colorless or pale wine yellow; otherwise yellowish white to honey yellow and dark brown. White streak. Transparent to translucent.

$\text{CaB}_2(\text{SiO}_4)_2$. Fuses easily to a colorless glass, imparting a green color to the flame. After ignition, it gelatinizes with hydrochloric acid; otherwise, only slightly acted upon by acid.

Occurs in dolomite at Danbury, Conn.; also at Russell, St. Lawrence County, N. Y.

Danburite is not a common mineral.

BARROWITE, $\text{CaAl}_2(\text{SiO}_4)_2$, is, according to Groth, isomorphous with danburite. It is sometimes considered a variety of anorthite. Has not been observed in crystals.

PSEUDOBRUKITE, $\text{Fe}_4(\text{TiO}_4)_3$.

Orthorhombic, bipyramidal class. $a : b : c = 0.9922 : 1 : 1.1304$. Small, rectangular, tabular crystals, resembling brookite. Dark brown to black in color. Hardness 6. Specific gravity 4.4 to 4.98. Streak ochre yellow. Submetallic luster. Appears red in transmitted light. Occurs in hypersthene andesite in Transylvania; in the lavas on Mt. Vesuvius; also in Norway.

EULYTITE GROUP

The compound $\text{Bi}_4(\text{SiO}_4)_3$ is dimorphous. It occurs as eulytite, cubic, and agricolite, monoclinic. Both of the minerals are quite rare.

EULYTITE, $\text{Bi}_4(\text{SiO}_4)_3$.

Cubic, hextetrahedral class. Crystals are generally trigonal tristetrahedrons, sometimes in combination with the tetrahedron and cube. Supplementary twins are common; also spherical groups.

Adamantine luster, inclining to greasy. Subtranslucent to opaque. Hardness 5 to 6. Specific gravity 6.1. No cleavage. Conchoidal fracture. Dark or reddish brown, grayish, straw yellow, colorless; rarely black. Colorless to yellow gray streak. May resemble sphalerite.

$\text{Bi}_4(\text{SiO}_4)_3$. Easily fusible. Readily decomposed by acids.

Occurs with quartz, bismite, native bismuth, chloanthite, and erythrite at Schneeberg and Johanngeorgenstadt, Saxony.

AGRICOLITE is the monoclinic modification of $\text{Bi}_4\text{Si}_2\text{O}_{12}$. It occurs in radial, spherical aggregates. Wine yellow, oily green, brown, or colorless. Physical properties like those of eulytite. Optically monoclinic. It occurs in very small quantities at Schneeberg and Johanngeorgenstadt, Saxony.

GARNET GROUP

This group embraces minerals which possess the general formula, $\text{R}''_3\text{R}'''_2(\text{SiO}_4)_3$, in which R'' may be calcium, magnesium, manganese, or ferrous iron, and R''' aluminium, ferric iron, or chromium. In the titaniferous varieties, some of the silicon may be replaced by titanium.

The members of the group crystallize in the hexoctahedral class of the cubic system.

GROSSULARITE, $\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$.

PYROPE, $\text{Mg}_3\text{Al}_2(\text{SiO}_4)_3$.

SPESSARTITE, $\text{Mn}_3\text{Al}_2(\text{SiO}_4)_3$.

ALMANDITE, $\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3$.

Uvarovite, $\text{Ca}_3\text{Cr}_2(\text{SiO}_4)_3$.

ANDRADITE, $\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3$.

Garnets are usually isomorphous mixtures of the above, hence, their chemical composition is rather complex. With the exception of pyrope, they are generally well crystallized. The forms and many of the physical properties of the different varieties are similar and will, therefore, be discussed together.

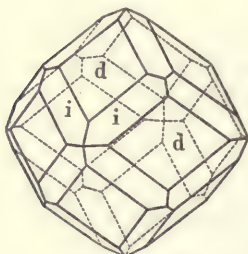


FIG. 116

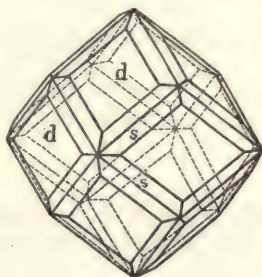


FIG. 117

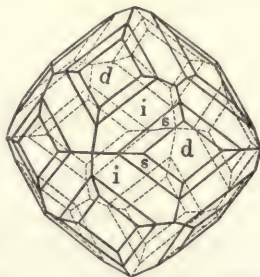


FIG. 118

Cubic, hexoctahedral class. Crystals may be either isolated or disseminated. The rhombic dodecahedron d and tetragonal trisoctahedron i ($m=2$), either alone or in combination, are the most common forms. The hexoctahedron s ($m=3$, $n=3/2$) is also frequently observed, very rarely, how-

ever, the octahedron or cube. Thirty-five forms have been noted, including representatives of the various forms of the hexoctahedral class. Some crystals are highly modified, figures 116, 117 and 118, but when not well developed, they are more or less spherical in outline. Diagonal striations are sometimes observed on the rhombic dodecahedron. Crystals may show a zonal development. Occurs in compact granular masses, and as sand and gravel.

Imperfect rhombic dodecahedral cleavage. Conchoidal to uneven fracture. Brittle. Hardness 6.5 to 7.5. Specific gravity 3.4 to 4.6, depending upon the composition. The precious varieties are transparent, the others commonly translucent to opaque. Vitreous to resinous luster. White streak. Sometimes colorless, but usually colored, commonly, red, brown, yellow, green, and black. All colors, except blue, are to be observed. Light colored garnets are generally transparent to translucent, dark colored varieties, translucent to opaque. Isotropic, sometimes shows anomalous double refraction, especially those varieties containing calcium.

$R''_3R'''_2(SiO_4)_3$. Depending upon the chemical composition six principal varieties may be differentiated. These varieties are, however, not often pure; most garnets are isomorphous mixtures of them. They generally fuse easily to a brownish or black glass, which is sometimes magnetic. Partially decomposed by acids. With the exception of uvarowite, all varieties gelatinize with acids after fusion. Garnets alter readily. Epidote, mica, chlorite, serpentine, hornblende, scapolite, orthoclase, oligoclase, calcite, hematite, and limonite have been observed occurring as pseudomorphs after garnets.

The garnet is a very common mineral. It occurs (1) in crystalline schists, (2) as a contact metamorphic mineral, (3) as a constituent of many eruptive rocks, (4) with various ore deposits, and (5) in secondary deposits.

The principal varieties are:

GROSSULARITE, Calcium-aluminium Garnet, $Ca_3Al_2(SiO_4)_3$.

Calcium may be partially replaced by ferrous iron, and aluminium by ferric iron. The specific gravity varies from 3.4 to 3.7. Colorless, white, pale emerald green, various shades of yellow, cinnamon brown, and rose red. *Cinnamon-stone*, *hessonite*, or *essonite* include the cinnamon colored, some yellowish, and yellowish red varieties. Grossularite is characteristic of metamorphosed impure calcareous rocks, and is thus commonly observed in the contact zone of intrusive igneous rocks and in crystalline schists associated with vesuvianite, wollastonite, diopside, scapolite, and other calcium silicates. Some localities are: Ceylon; Mussa Alp, Piedmont; Island of Elba; More-

los, Mexico; (colorless) Tellemark, Norway; Jordansmuehl, Silesia; Hungary; Monzoni district, Tyrol; Spain; Parsonsfield, Phippsburg, and Rumford, Me.; Warren, N. H.

PYROPE, Magnesium-aluminium Garnet, $\text{Mg}_3\text{Al}_2(\text{SiO}_4)_3$.

May contain calcium and bivalent iron replacing some of the magnesium. Specific gravity 3.7 to 3.75. Deep red to black in color. Often clear and transparent. Commonly used for gem purposes. The pyrope of South Africa is sometimes called *cape ruby*. Pyrope is found chiefly in basic igneous rocks such as peridotites and the serpentine derived from them. It is rarely observed in well developed crystals. Often surrounded by a shell of other minerals to which the term *kelyphite* has been given. Pyrope is often considered an important associate of the diamond. It is common in Hungary, especially at Meronitz, Triblitz, and Krems; Zöblitz and Greifendorf, Saxony; Kimberley and other diamondiferous localities in South Africa; Ceylon; Syracuse, N. Y.; Murfreesboro, Pike County, Ark.; Elliott County, Ky.

SPESSARTITE, Manganese-aluminium Garnet, $\text{Mn}_3\text{Al}_2(\text{SiO}_4)_3$.

Manganese and aluminium may be replaced by bivalent and trivalent iron, respectively. Specific gravity 4 to 4.3. Brownish to hyacinth red in color. Spessartite occurs in granite, quartzite, and with topaz in rhyolite. When crystallized, usually as tetragonal trisoctahedrons. The principal localities are Aschaffenburg, Bavaria; Ilfeld, Hartz Mts.; Pfitschthal, Tyrol; St. Marcel, Piedmont; Island of Elba; Arendal, Norway; Haddam, Conn.; Amelia Court House, Amelia County, Va.; Nathrop, Colo.

ALMANDITE, Iron-aluminium Garnet, Carbuncle, $\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3$.

May contain magnesium and trivalent iron. Specific gravity 3.9 to 4.2. Deep red to brownish red or black in color. The transparent red varieties, known as precious garnets, are used for gem purposes; translucent varieties are called common garnets. Almandite occurs commonly in gneiss, crystalline—mica, talc, chlorite, and hornblende—schists, granulite, granite, eclogite, and some andesites. The common associates are staurolite, cyanite, andalusite, tourmaline, and cordierite. Often well crystallized, but occurs also as rounded grains and pebbles. Some localities are Falun, Sweden; various places in Saxony and Silesia; Zillerthal, Tyrol; Eppenruth, Bavaria; Saint Gotthard district, Switzerland; Ceylon; Finland; Brazil; Windham, Me.; Hanover, N. H.; Brookfield and Brimfield, Mass.; Delaware County, Pa.;

Chaffee County, Colo.; at the Spurr Mountain Iron Mine, Lake Superior region, altered to a chloritic decomposition product. In Warren and Essex counties, N. Y., it is mined for abrasive purposes.

Uvarovite, Calcium-chromium Garnet, Ouvarovite, Uwarowite, $\text{Ca}_3\text{Cr}_2(\text{SiO}_4)_3$.

May contain some aluminium. Emerald green in color. Vitreous luster. When somewhat decomposed is dull and dirty green. Hardness 7.5. Specific gravity 3.4 to 3.52. Crystals are usually small. It is not a common variety. Found with chromite in serpentine, also in gneiss and crystalline limestone. Occurs in various places in the Ural Mountains; Texas, Lancaster County, Pa.; New Idria, Cal.; Orford, Canada.

ANDRADITE, Calcium-iron Garnet, Black Garnet, Common Garnet, $\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3$.

The composition varies considerably. May contain manganese, ferrous and ferric iron, titanium, or yttrium. The color may be brownish red, brown, grayish black, black, also various shades of yellow or green. *Topazolite* is a variety resembling topaz in color and transparency. May be also green. *Demantoid* is a grass green variety. It is found in serpentine and is used as a gem. *Schorlomite* and *melanite* are black varieties containing much titanium. *Aplome* is a common variety of andradite, usually green, yellow, or brown. These garnets occur in nepheline syenite, phonolite, serpentine, chloritic schists, and crystalline limestones. Some localities are: Kaiserstuhl, Baden; Schwarzenberg and Breitenbrunn, Saxony; Moravicza, Dog-nacska, Dobschau, Hungary; Pfitschthal and Zillerthal, Tyrol; Zermatt, Switzerland; Island of Elba; Arendal, Norway; Sala, Långbanshytta and Stålmalms mines, Sweden; Pitkaeranta, Finland; various places in the Ural Mountains; New Haven, Conn.; Franconia, N. H.; Franklin, N. J.; Magnet Cove, Ark.

The various transparent varieties are often used for gem purposes. About 7,000 tons of compact, massive garnet are mined annually for abrasive purposes. Small garnets are sometimes used as jewels in watches of a cheaper grade.

Diopase, H_2CuSiO_4 .

Hexagonal, trigonal rhombohedral class. $a : c = 1 : 0.5281$. Found commonly in small, prismatic crystals. The unit prism of the second order m usually predominates and is in combination with a negative rhombohedron

of the first order r and the rhombohedron of the third order s ($p = 18/17$, $m = 9/4$), figure 119. The latter form is often indicated by a very narrow face. Twins are very rare. Occurs also in druses and massive. Crystals are often rather complex.

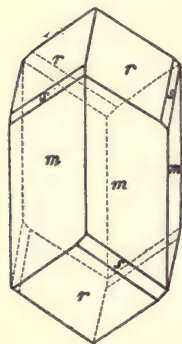


FIG. 119

Perfect rhombohedral cleavage. Brittle. Conchoidal to uneven fracture. Hardness 5. Specific gravity 3.3. Emerald to dark green in color. Green streak. Vitreous luster. Transparent to opaque.

H_2CuSiO_4 . Infusible. Turns black. Colors the flame green. Gelatinizes with acids. Forms a blue solution with a separation of silica when acted upon by ammonia and ammonium carbonate.

It occurs with calcite in limestone on the hill of Altyn-Tuebe in the Kirghiz Steppe, Russia; Rezbanya, Hungary; Copiapo, Chili; Peru; Clifton, Graham County, and Riverside, Pinal County, Ariz.

Dioptase is sometimes used as a gem.

Chrysocolla, $\text{H}_2\text{CuSiO}_4 + \text{H}_2\text{O}$.

Apparently amorphous. Never found in crystals. Occurs in earthy masses, incrustations, and seams. Sometimes reniform, botryoidal, and stalactitic. Often has an opal-like appearance.

Conchoidal fracture. Hardness 2 to 4. Specific gravity 2 to 2.2. Shining greasy, vitreous luster. Translucent to opaque. Various shades of green and blue, when impure brown to black. Pure varieties possess a greenish white streak.

$\text{H}_2\text{CuSiO}_4 + \text{H}_2\text{O}$. Pure and fresh varieties appear to possess the composition given. The presence of varying amounts of opaline material, aluminium silicates, limonite, and the oxides of copper and manganese cause the chemical and physical properties of chrysocolla to vary greatly. Blackens and yields water when heated in a closed tube. Infusible, but colors the flame green. Decomposed by acids but does not gelatinize.

Chrysocolla is a secondary mineral, formed by the decomposition of various copper ores, such as, chalcopyrite, tetrahedrite, cuprite, and so forth. It is usually found in the zone of oxidation of copper deposits. The common associates are malachite, azurite, and limonite. It occurs pseudomorphous after atacamite, azurite, cerussite, and labradorite. Some localities are Cornwall, Eng.; Ober-Rochlitz, Bohemia; Kupferberg, Bavaria; Silesia; various places in Hungary; Ural Mountains; Clifton and Bisbee copper districts, Arizona; Lake Superior copper district; in fact in all important copper localities.

It is an ore of copper and sometimes may be substituted for turquoise.

Prehnite, $H_2Ca_2Al_2(SiO_4)_3$.

Orthorhombic, pyramidal class. $a : b : c = 0.8401 : 1 : 1.1097$. Crystals are usually tabular or prismatic, more or less curved and arranged in sheaf-like groups. Distinct individual crystals are very rare. Also botryoidal, globular, and stalactitic, often with a radial fibrous structure. The common forms are the basal pinacoid, unit prism with an angle of $80^\circ 12'$, and the macro- and brachypinacoids.

Distinct basal and indistinct prismatic cleavages. Uneven fracture. Hardness 6 to 7. Specific gravity 2.8 to 3. Waxy vitreous luster, somewhat pearly on the basal pinacoid. Transparent to translucent. Colorless or white, but usually light green, apple green, oil green, also yellow green. Colorless streak. Hemimorphism is revealed by the pyroelectric properties.

$H_2Ca_2Al_2(SiO_4)_3$. May contain as much as 7% Fe_2O_3 . Yields water upon ignition at a comparatively high temperature in a closed tube. Fuses easily with intumescence to white yellow glass. Decomposed by acids after ignition. Prehnite alters to chlorite. It occurs as a pseudomorph after analcite, laumontite, and natrolite.

Prehnite is a secondary mineral and, hence, occurs in fissures and cavities in diorite, basalt, diabase, melaphyre, gabbro, and the like. It is usually associated with pectolite, datolite, epidote, calcite, and the various zeolites. In the Lake Superior copper district it occurs with native copper. Other localities are: Bourg d'Oisans, Dauphine, France; Weilburg and Dillenburg, Nassau; Fassathal, Tyrol; various places in Switzerland and Italy; Kongsberg, Norway; Peru; Chile; South Africa; Farmington, Conn.; Essex County, N. Y.; Bergen Hill, N. J.; Cornwall, Pa.

Prehnite is sometimes used for gem purposes.

CHLORASTROLITE, a greenish, fibrous mineral occurring in small spherical aggregates in the melaphyre amygdaloid of Isle Royale, Lake Superior, is often considered an impure prehnite. It is sometimes also thought to be closely related to thomsonite in composition. Subtransparent. Possesses a beautiful chatoyancy. Hardness 5 to 6. Specific gravity 3.18. Chlorastrolite is cut as a gem.

Axinite, $R''_7R'''_4B_2(SiO_4)_8$.

Triclinic, pinacoidal class. $a : b : c = 0.4927 : 1 : 0.4511$, $\alpha = 82^\circ 54'$, $\beta = 88^\circ 9'$, $\gamma = 131^\circ 33'$. Crystals are generally broad and tabular with sharp edges. Figure 120 consists of the unit tetra-pyramids x and r , hemiprisms M and m , macrodome s , and the macropinacoid a . The prism faces are often striated vertically. The habit varies considerably. Crystals may be very complex. Over 40 forms have been observed. Occurs also in lamellar and granular masses.

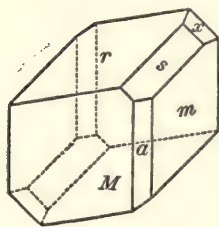


FIG. 120

Several cleavages are observable. Conchoidal fracture. Brittle. Hardness 6 to 7. Special gravity 3.3. Vitreous luster. Transparent to translucent. Uncolored streak. Clove

brown, pearl gray, plum blue, honey yellow and greenish yellow in color. Often coated and intergrown with chlorite.

$R''_7R'''_4B_2(SiO_4)_8$. R'' is chiefly calcium, but may be also iron, manganese, magnesium, and hydrogen, while R''' is trivalent iron and aluminum. The average content of B_2O_3 is about 6%. Fuses easily with intumescence to a dark green glass, coloring the flame a pale green. Gelatinizes with acid after ignition.

Axinite occurs in fissures and cavities in the older silicate rocks especially diabase, hornblende schist, and more rarely in granites, usually the result of pneumatolytic action. Also found sparingly in ore deposits. Some localities are: Bourg d'Oisans, Dauphine, France; on Mount Skopi and Saint Gotthard, Switzerland; Island of Elba; Andreasberg, Saxony; Monzoni, Tyrol; Cornwall, England; Kongsberg, Norway; Nordmarken and Dannemora, Sweden; also in Hungary, Ural Mountains, Japan, Peru, and Chile; Wales and Phippsburg, Me.; Cold Spring, N. Y.; Bethlehem, Pa.; and Franklin Furnace, N. J.; Bonsall, and Consumers Mine, Cal.

Sometimes used as a gem.

MICA GROUP

The members of the mica group have a great many characteristics in common. While crystals are often apparently hexagonal or orthorhombic in development, they all, nevertheless, belong to the monoclinic system and possess practically the same elements of crystallization. The prism angle usually approximates 120° . Twin crystals are not uncommon. The twinning plane is perpendicular to the basal pinacoid and nearly parallel to a face of the unit prism. In some cases the basal pinacoid is the composition plane, in others the unit prism. Polysynthetic twins according to this common law, the *mica law*, are also to be observed. Now and then the gliding planes, $3a : b : c$ and $2a : \infty b : c$, act as twinning planes. These are inclined at an angle of about 67° to the basal pinacoid and the resulting twins are somewhat step-like in their development.

The micas possess an excellent basal cleavage. This cleavage is sometimes referred to as the most perfect to be observed on minerals. The cleavage laminae are more or less elastic. By pressing upon or striking a cleavage surface a blow with a dull conical point, *pressure* and *percussion figures* are produced. These figures possess three or six rays, more commonly six, and have a definite orientation. One of the rays in the pressure figures is perpendicular to the edges formed by the basal and clinopinacoids, while in the percussion figures the rays extend nearly parallel to them and the prismatic edges, see figures 121 and 122. Natural pressure figures are sometimes observed.

The optical properties of the micas can be easily studied in cleavage fragments, for these show interference figures, inasmuch as the acute bisectrix is almost normal to the basal pinacoid. The angle of the optic axes varies greatly. In biotite the angle may be almost zero, hence, the figure is

sometimes apparently uniaxial. In phlogopite the angle is commonly about 15° , while in the other micas it varies from 50° to 75° . In micas of the *first class* the plane of the optic axes is normal to the plane of symmetry. When the optical plane is parallel to the plane of symmetry the micas are said to belong to the *second class*.

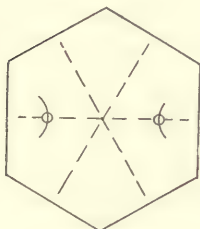


FIG. 121

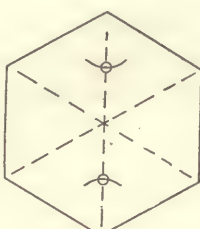


FIG. 122

From the chemical standpoint, the micas are silicates of varying composition of aluminium and potassium, containing hydrogen, magnesium, iron (ferrous and ferric), sodium, lithium, and fluorine. The content of silica varies between 33% and 55%. Several theories have been advanced to explain the rather complex composition of the members of the group. According to Clarke, the micas are derived from the hypothetical orthosilicate $\text{Al}_4(\text{SiO}_4)_3$, while Tschermak considers them as mixtures in varying proportions of $\text{H}_3\text{Al}_3(\text{SiO}_4)_3$ and $(\text{Mg,Fe})_6(\text{SiO}_4)_3$.

Six varieties are commonly differentiated:

BIOTITE, $(\text{K,H})_2(\text{Mg,Fe})_2(\text{Al,Fe})_2(\text{SiO}_4)_3$
 PHLOGOPITE, $(\text{K,H})_5\text{Mg}_3\text{Al}(\text{SiO}_4)_3$
 MUSCOVITE, $\text{H}_2\text{KAl}_3(\text{SiO}_4)_3$
 PARAGONITE, $\text{H}_2\text{NaAl}_3(\text{SiO}_4)_3$
 Lepidolite, $(\text{Li,K})_2(\text{F,OH})_2\text{Al}_2\text{Si}_3\text{O}_9$
 ZINNWALDITE, $(\text{Li,K})_3(\text{F,OH})_2\text{Al}_3\text{FeSi}_5\text{O}_{16}$

0.5777 : 1 : 2.1932
 $\beta = 95^\circ 2'$
 (Tschermak)

All the micas yield water when heated to a high temperature in a closed tube. They fuse with difficulty.

The micas are important rock forming minerals and occur extensively in igneous and metamorphic rocks. Some sedimentary rocks also contain considerable quantities of mica.

BIOTITE, Magnesium-iron Mica, Black Mica, $(\text{K,H})_2(\text{Mg,Fe})_2(\text{Al,Fe})_2(\text{SiO}_4)_3$.

Monoclinic, prismatic class. $a : b : c = 0.5777 : 1 : 2.1932$, $\beta = 95^\circ 2'$. Crystals are usually tabular with an hexagonal or rhombohedral habit. This habit in connection with the very small angle of the optic axes caused

biotite to be considered for a long time as rhombohedral and uniaxial. According to Hintze about forty crystallographic forms have been observed. The usual combination consists of the basal pinacoid *c*, clinopinacoid *b*, and the positive and negative hemipyramids *m* and *o*, see figure 123. Crystals are often striated horizontally, due to the alternation of *m* and *o*. Good crystals are rarely found. Twins are observed with the basal pinacoid as the composition plane, also with the twinning plane parallel to either $3a:b:c$ or $2a:\infty b:c$, see page 214. Generally occurs in disseminated scales.

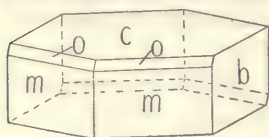


FIG. 123.

Highly perfect basal cleavage, laminae are more or less elastic and may be extremely thin; sometimes given as 0.001 of an inch in thickness. Splendent, pearly, and submetallic luster. Hardness 2.5 to 3. Specific gravity 2.7 to 3.2. Transparent to opaque. Dark in color,—dark brown, black; more rarely, light brown or greenish. Strong pleochroism. Double refraction strong and negative. Asterism is sometimes to be noted.

There are two varieties of biotite: (1) *Anomite*, having the plane of the optic axes perpendicular to the plane of symmetry, and (2) *Meróxene* in which the optical plane extends parallel to the plane of symmetry. These varieties may be designated as micas of the first and second classes, respectively, see page 215. Meróxene is by far the more common variety.

$(K,H)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$. The composition varies greatly. Thus, SiO_2 from 35% to 45%, some of which may be replaced by TiO_2 ; MgO from 10% to 30%, which may be replaced partially or almost entirely by FeO ; Al_2O_3 from 11% to 20%, replaced to some extent by Fe_2O_3 ; K_2O , replaced by some Na_2O , from 5% to 11%; fluorine may replace some of the hydrogen. *Lepidomelane* contains a high percentage of FeO and Fe_2O_3 , and but little MgO . Meróxene contains only a very small amount of iron, while anomite is characterized by a high percentage of bivalent elements. Some biotite contains small amounts of chromium, barium, and manganese. Only slightly attacked by hydrochloric acid; completely, however, by hot concentrated sulphuric. Fusible on the thin edges. The darker varieties fuse more readily. Biotite alters to chlorite, or to epidote, quartz, and iron oxide.

Biotite is often considered the most common of all micas. It is an important constituent of many igneous and metamorphic rocks, such as, granites, diorites, gabbros, syenites, porphyries, gneisses, and mica schists. It is often developed by contact metamorphism. On account of its tendency to decompose it is not important in sedimentary rocks.

The various varieties of biotite are of little or no use, commercially.

PHLOGOPITE, Amber Mica, Bronze Mica, Magnesium Mica, $(\text{K,H})_3\text{Mg}_3\text{Al}(\text{SiO}_4)_3$.

Monoclinic, prismatic class. The elements of crystallization are the same as given for biotite. Crystals usually resemble those of biotite in form and habit; large, coarse crystals are sometimes observed. They may possess a pseudo-orthorhombic or trigonal development. Twinned according to the laws described under biotite. Occurs commonly in disseminated scales, plates, and aggregates.

Highly perfect basal cleavage. Thin laminae are tough and elastic. Specific gravity 2.75 to 2.97. Hardness 2.5 to 3. Pearly to submetallic luster. The color may be silvery gray, yellow, brown, greenish, or copper red. Cleavage laminae are transparent. Phlogopite is a mica of the second class, see page 215. The optic angle is about 15° , although it may be smaller. Often shows distinct asterism.

$(\text{K,H})_3\text{Mg}_3\text{Al}(\text{SiO}_4)_3$. Usually contains a small amount of FeO , 1 to 2%; potassium may be replaced by sodium and fluorine. The amount of MgO varies between 27 and 29%, the SiO_2 between 41 and 44%. Whitens and fuses on thin edges. Hydrochloric acid acts but slightly upon phlogopite, while hot concentrated sulphuric acid decomposes it readily.

Phlogopite occurs in crystalline limestones, dolomites, schists and in serpentine. Important localities: Pargas in Finland; Aeker, Sweden; Fassathal, Tyrol; St. Lawrence and Jefferson counties, N. Y. Extensive deposits of economic importance occur in Canada. According to Cirkel, the Canadian phlogopite occurs in dikes penetrating gneiss or limestone, or in contact and pocket deposits. It is commonly associated with pyroxene, apatite, and calcite. Sydenham and Burgess, Ontario, furnish large quantities of phlogopite. Some of the crystals from the Lacey mine, near Sydenham, measured seven feet across the cleavage planes.

It is used chiefly as an insulator in electrical work.

MUSCOVITE, White Mica, Potash Mica, Isinglass, $\text{H}_2\text{KAl}_3(\text{SiO}_4)_3$.

Monoclinic, prismatic class. For elements of crystallization, see biotite, page 215. Crystals are usually tabular with an orthorhombic or hexagonal outline. Sometimes tapering, pyramidal habits are also noted. The forms observed most frequently are the basal pinacoid, unit prism, clinopinacoid, and the clinodome, $\infty a : b : c$. Crystals are often large and rough, measuring at times several feet in diameter, and are called blocks or books. Due to partings in several directions at about right angles to the basal pinacoid, which interrupt the true cleavage, these crystals are often

called *ribbon*, *ruled*, or *A mica*. In *wedge mica* the crystals are thicker at one end than at the other. Twins are common, the basal pinacoid being the composition plane. Occurs also in scaly, foliated, and plumose aggregates; sometimes compact and cryptocrystalline.

Highly perfect cleavage parallel to the basal pinacoid, permitting very thin, elastic leaves to be split. Hardness 2 to 3. Specific gravity 2.75 to 3.1. Transparent to translucent. Pearly to metallic luster. Colorless, when pure, but usually yellowish, brownish, greenish, or reddish. Some shades of brown and reddish muscovite are termed *rum* or *ruby mica*. Uncolored streak. Strong double refraction. Negative. The plane of the optic axes is perpendicular to the plane of symmetry. Muscovite is, hence, a mica of the first class. Sometimes shows asterism.

$\text{H}_2\text{KAl}_3(\text{SiO}_4)_3$. Muscovite proper contains about 45% of SiO_2 . The variety with about 52% of SiO_2 is called *phengite*. From 8 to 10% of the potassium is generally replaced by sodium. Small amounts of magnesium, calcium, iron, and fluorine are also commonly noted. *Fuchsite* contains small amounts of chromium while *roscoelite* has considerable vanadium replacing the aluminium. Fuses with some difficulty to a grayish or yellowish glass. Not attacked by the common acids. *Sericite* and *damourite* are more or less altered varieties of muscovite. The term *sericite* is sometimes applied to unaltered muscovite occurring in aggregates of fine scales with a silky luster but without distinct cleavage.

Muscovite is generally considered the most common mica. It occurs in granites and syenites, especially in pegmatite veins where pneumatolytic action has been effective. It is also common in metamorphic rocks, such as gneisses and schists. Occurs furthermore in some limestones and fragmental rocks. The usual associates of muscovite are feldspar, quartz, tourmaline, beryl, spodumene, samarskite, and garnet. Deposits of muscovite of commercial value occur in North Carolina, South Dakota, Alabama, South Carolina, Colorado, New Hampshire, Idaho, Georgia, Virginia, New Mexico, and Maine. Some of the principal producing localities are in Mitchell, Yancey, Macon, Jackson, Haywood, and Ashe counties, North Carolina; Custer County, South Dakota; Grafton and Cheshire counties, New Hampshire. Deposits of excellent muscovite also occur in Ottawa and Berthier counties, Quebec, Canada. The muscovite mined in the United States during 1908 was valued at \$267,925.

The principal use of muscovite is in the manufacture of windows for coal, gas, and oil stoves, gas-lamp chimneys, lamp shades, and so forth. Scrap and waste mica, that is, material too small to be cut into sheets, is ground in large quantities for the manufacture of wall paper, lubricants, fancy paints, and for electrical insulators. Very large amounts of muscovite

and phlogopite are used for insulating purposes in electrical apparatus and machinery, such as, dynamos, motors, high voltage induction apparatus, switchboards, lamp sockets and the like. Much of the *sheet* mica used for this purpose is made by cementing small pieces of scrap or waste mica together and is commonly known by the trade name *micanite*.

In 1908 the prices per pound of selected sizes of muscovite were as follows: 2 by 2 inches \$0.87, 3 by 3 inches \$2.75, 3 by 4 inches \$3.25, 6 by 8 inches \$6.75.

PARAGONITE, Sodium Mica, $\text{H}_2\text{NaAl}_3(\text{SiO}_4)_3$.

Monoclinic, prismatic class. The elements of crystallization are the same as for biotite. Occurs in compact and fine scaly aggregates, which often resemble sericite. Massive and laminated.

Perfect basal cleavage. Hardness 2 to 3. Specific gravity 2.8 to 2.9. White, grayish, greenish white, or yellow in color. Pearly luster. Large optical angle. Very strong double refraction.

$\text{H}_2\text{NaAl}_3(\text{SiO}_4)_3$. Fuses with great difficulty; some varieties exfoliate. Not attacked by acids.

Paragonite is not a common mica. Its common associates are cyanite, staurolite, garnet, and tourmaline. It is generally found in metamorphic rocks. At Monte Campione in the St. Gotthard Alps, Switzerland, it forms a schist and contains the minerals, referred to, as associates. It is also found in Pfischthal and Zillerthal, Tyrol; Unionville, Pa.

Lepidolite, Lithium Mica, $(\text{Li},\text{K})_2(\text{F},\text{OH})_2\text{Al}_2\text{Si}_3\text{O}_{10}$.

Monoclinic. The elements of crystallization are unknown as measurable crystals have never been found. According to Tschermak, they are undoubtedly very similar to those of muscovite. Twins and trillings according to the mica law are sometimes observed. Usually occurs in scaly, granular masses; often looks like granular limestone. Also as tabular, cleavable plates.

Perfect basal cleavage. Hardness 2 to 4. Specific gravity 2.8 to 2.9. Pearly luster. Rose-red or lilac in color, also white, gray, greenish, or brown. White streak. Translucent. Plane of the optic axes is perpendicular to the plane of symmetry, that is, it is a mica of the first class. Angle of the optic axes varies from 50 to 80°.

$(\text{Li},\text{K})_2(\text{F},\text{OH})_2\text{Al}_2\text{Si}_3\text{O}_{10}$. Fluorine varies from about 3.5 to 10.5%; Li_2O 1.25 to 5.9%; SiO_2 from 49 to 52%. Some varieties from Maine contain considerable amounts of rubidium and caesium. Colors the flame red and fuses easily to a white glass. After fusion is easily acted upon by acids.

Occurs in pegmatite veins, in granites and gneisses, the result of pneumatolytic action. The common associates are tourmaline, amblygonite, spodumene, cassiterite, and topaz. Sometimes intergrown with muscovite. Some localities are: Rozena, Moravia; Penig, Saxony; Utö, Sweden; Island of Elba; Paris, Hebron, Auburn, and Rumford, Maine; Chesterfield,

Mass.; San Diego County, Cal. Rubbelite, the red lithium variety of tourmaline, is often found embedded in granular lepidolite.

It is an important source of lithium compounds.

COOKEITE, $\text{Li}(\text{Al}, 2\text{OH})_3(\text{SiO}_3)_2$, is probably an alteration product of lepidolite or tourmaline with which it occurs at Hebron, Me.

ZINNWALDITE, Lithium-iron Mica, $(\text{Li}, \text{K})_3(\text{F}, \text{OH})_2\text{Al}_3\text{FeSi}_5\text{O}_{16}$.

Monoclinic, prismatic class. The elements of crystallization are similar to those of biotite. Distinct tabular crystals with a pseudo-hexagonal outline are usually penetration trillings. The basal pinacoid generally shows a complex system of striations. Occurs also in fan shaped and rosette groups and in isolated aggregates. Sometimes coarse granular and cleavable.

Perfect basal cleavage. Hardness 2 to 3. Specific gravity 2.8 to 3.1. Pearly to metallic luster. Pale violet, gray, yellowish, various shades of brown, and more rarely dark green in color. It is a mica of the first class, see page 215. The angle of the optic axes varies from almost 0° to about 50° .

$(\text{Li}, \text{K})_3(\text{F}, \text{OH})_2\text{Al}_3\text{FeSi}_5\text{O}_{16}$. Composition varies greatly; SiO_2 44 to 47%; F, 2 to 8%; Li_2O , 1 to 5%; FeO , 10 to 12%; K_2O , 5 to 13%. Some sodium may be present and a portion of the fluorine may be replaced by the hydroxyl. Fuses easily to a dark colored glass, coloring the flame reddish. Attacked by acids, especially when finely powdered.

Associated with topaz, scheelite, fluorite, quartz, cassiterite, and so forth, it occurs in cassiterite bearing granites and gneisses. It is the result of pneumatolytic action and is not a very common mineral. The principal localities are Zinnwald, Bohemia; Altenberg, Saxony; Cornwall, England; Nararsuk, Greenland; York region, Alaska.

GLAUCONITE, $\text{Fe}'''\text{KSi}_2\text{O}_6 \cdot \text{H}_2\text{O}?$

Probably monoclinic, analogous to the micas. Never in crystals, but as granular grains or sand resembling gunpowder, or disseminated in sandstone or marl. Sometimes in fragile aggregates. Specific gravity 2.3. Composition varies. Clarke suggests the formula given. Found as *green sand* in rocks of all ages, especially cretaceous and tertiary. Large quantities of this sand, containing from 75 to 90% of glauconite, occur in Northern Prussia along the south shore of the Baltic Sea and contains amber. Also found in southern New Jersey and Texas. On account of the content of potassium, it is used as a fertilizer.

CELADONITE, also written *seladonite*, is very similar to glauconite. Clarke believes that they may be identical. Usually earthy. Very soft. Specific gravity 2.8 to 2.9. Apple to dark green in color. Is a decomposition product of hornblende and augite. Occurs in the Fassathal, Tyrol, and in the Lake Superior district.

CLINTONITE GROUP

The members of this group resemble the micas in form and cleavage but are harder and brittle. They are often termed the *brittle micas*. Chemically, they are basic silicates of calcium, magnesium, and aluminium, and are differentiated from the micas by the absence of the alkalis.

The important members are:

Margarite, $H_2CaAl_4Si_2O_{12}$.

XANTHOPHYLLITE, $H_8(Mg,Ca)_{14}Al_{16}Si_5O_{52}$.

BRANDISITE, $H_8(Mg,Ca)_{12}Al_{12}Si_5O_{44}$.

CLINTONITE, $H_6(Mg,Ca)_{10}Al_{10}Si_4O_{36}$.

OTTRELITE, $H_2FeAl_2Si_2O_9$.

CHLORITOID, $H_2FeAl_2SiO_7$.

$$\begin{array}{ccc} a & : & b : c \\ 0.577 & : & 1 : 0.577 \\ \beta = 109^\circ 35\frac{1}{2}' \end{array}$$

They have been referred to the prismatic class of the monoclinic system. A rhombohedral habit is characteristic. The elements of crystallization, given above, are for *valuewite*, a variety of xanthophyllite. The other members of the group do not occur in measurable crystals.

Margarite, Pearl Mica, $H_2CaAl_4Si_2O_{12}$.

Monoclinic. Well developed crystals are rare. The elements are thought to be very similar to those of biotite. Usually in thin six sided plates or lamellar aggregates; also in granular, scaly masses.

Perfect basal cleavage, but not as easy as on the micas proper. Laminae are brittle and inelastic. Hardness 3 to 4.5. Specific gravity 3. Pearly luster on the basal pinacoid, vitreous on the lateral faces. Translucent. White, reddish white, pink, yellow, and pearly gray in color. It is a mica of the first class, see page 215. Large angle of the optic axes, about 120° .

$H_2CaAl_4Si_2O_{12}$. The composition varies somewhat. Magnesium, sodium, and fluorine may be present. Exfoliates and fuses with difficulty on the edges. Slightly attacked by acids. *Dudleyite* is brownish yellow alteration product.

Occurs in altered and metamorphosed rocks. As an alteration product, it is commonly associated with corundum and emery. Some localities are the island of Naxos and other places in the Grecian archipelago and Asia Minor; Greiner, Tyrol; Chester, Mass.; Peekskill, N. Y.; Gainesville, Ga.; Unionville, Pa.; Dudleyville, Ala.

XANTHOPHYLLITE, $H_8(Mg,Ca)_{14}Al_{16}Si_5O_{52}$.

Monoclinic. The variety known as *valuewite* occurs in distinct crystals with the ratio: $a : b : c = 0.5774 : 1 : 0.5773$, $\beta = 109^\circ 35\frac{1}{2}'$. They are usually tabular parallel to the basal pinacoid. Crystals sometimes appear to be a combination of the basal pinacoid with a rhombohedron, but are in reality monoclinic. Interpenetration twins and trillings commonly appear to be simple crystals. The basal pinacoid is generally smooth and shiny, the lateral faces rough and rounded. Xanthophyllite is generally found in aggregates and crusts.

Perfect basal cleavage. Hardness 4 to 5 on the basal pinacoid, 5 to 6 on the lateral faces. Specific gravity 3 to 3.1. Vitreous luster, on cleavage surfaces pearly. Aggregates are wax yellow, crystals leek to bottle green. Transparent to translucent. Infusible, but becomes cloudy. Decomposed with difficulty by hot hydrochloric acid. Associated with magnetite, spinel, and garnet it occurs in talc and chloritic schists in the Ural Mountains.

BRANDISITE, Disterrite, $H_8(Mg,Ca)_{12}Al_{12}Si_5O_{44}$.

Monoclinic. Usually in thin tabular plates which appear to be repeated twins according to the mica law. Perfect basal cleavage. Hardness 5 on the basal pinacoid, otherwise 6 or more. Specific gravity 3 to 3.1. Rather brittle. Vitreous luster. Sub-transparent. Leek to dark green, rarely reddish gray, in color. Infusible, but turns white. Not easily acted upon by acids. Occurs as a contact mineral associated with fassaite and spinel in the Monzoni district, Tyrol.

CLINTONITE, Seybertite, $H_6(Mg,Ca)_{10}Al_{10}Si_4O_{36}$.

Monoclinic. Crystals resemble those of brandisite. Usually thick, apparently hexagonal, plates with rough lateral faces. Also in foliated masses. Perfect basal cleavage. Very brittle. Hardness 4 to 5. Specific gravity 3.1. Submetallic luster on the basal pinacoid, resinous on cleavage surfaces, otherwise vitreous. Transparent to translucent. Yellowish, reddish brown, or copper red in color. Infusible, but becomes white and opaque. Easily and completely decomposed by concentrated hydrochloric acid. Associated with amphibole, pyroxene, chondrodite, spinel, and graphite, it occurs in serpentine with granular limestone at Amity and Warwick, Orange County, N. Y.

CHRY SOPHANE, HOLMITE, and HOLMESITE are synonyms for clintonite.

OTTRELITE, $H_2FeAl_2Si_2O_9$.

Monoclinic. Occurs in small, elongated plates or scales with an hexagonal outline. Gray, greenish gray, or greenish black in color. Ottrelite is usually considered a variety of chloritoid, although it differs somewhat chemically. It is characterized by a large percentage of MnO. It occurs in argillaceous schists near Ottrez, Belgium; Northern Michigan, Vermont, and other places.

CHLORITOID, $H_2FeAl_2SiQ_7$.

Monoclinic. Crystals with distinct outlines are rare. Usually in plates which may be hexagonal, also in disk, spindel, or lenticular shaped grains, and foliated, curved scaly, fan and sheaf like masses or aggregates.

Perfect basal cleavage. Brittle. Hardness 5 to 7. Specific gravity 3.4 to 3.6. Vitreous to pearly luster on the cleavages, on the lateral surfaces resinous. Almost opaque. Gray, greenish gray, greenish black, grass green, or black in color. Uncolored, grayish, or greenish gray streak. Plane of the optic axes is parallel to the plane of symmetry. Large optic angle. Strongly pleochroic.

$H_2FeAl_2SiO_7$. Some of the iron may be replaced by magnesium or manganese. Exfoliates slightly and fuses with difficulty to a black magnetic mass. The fine powder is decomposed by sulphuric acid. Alters to muscovite and penninite.

Chlorotoid occurs in phyllite, quartzite, mica schist, and metamorphosed sedimentary rocks. Often associated with glaucophane. Some localities are St. Marcel, Pied-

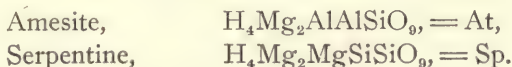
mont, Italy; Kossoibrod, Ural Mountains; Zermatt, Switzerland; Natick, R. I.; Sterling, Mass.

MASONITE, NEWPORTITE, PHYLITE, SALMITE, SISMONDINE, and BARYTOPHYLLITE are more or less synonymous with chloritoid.

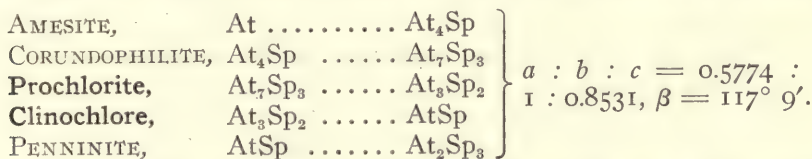
CHLORITE GROUP

This group contains a considerable number of minerals which are closely related to the micas, especially with regard to crystal form, scaly or foliated habit, and cleavage. Cleavage laminae are, however, tough and comparatively inelastic. These minerals are silicates of aluminium or trivalent iron, with magnesium, bivalent iron, or manganese, but are much more basic than the micas. They are also free from alkalis and calcium, and yield water when heated in a closed tube. Characteristic is the green color commonly observed in silicates containing ferrous iron.

According to Tschermak, the members of this group form a series of isomorphous mixtures of the two silicates:



The Al_2 group in amesite is considered as being replaced by $MgSi$ in serpentine. Such replacements are, according to Groth, rather common. If the amesite molecule be represented by At , and that of serpentine by Sp , then the general composition of these minerals may be expressed as follows:



These minerals crystallize in the monoclinic system but clinochlore and penninite are the only ones occurring in well developed crystals. A rhombohedral habit is not uncommon. The elements of crystallization given above are for clinochlore.

AMESITE, $H_4Mg_2Al_2SiO_9$.

The composition may vary from that given to that of the mixture At_4Sp . Six sided plates and foliated aggregates. Resembles green talc. Apple green in color. Hardness 2.5 to 3. Specific gravity 2.7. Pearly luster on cleavage surface. Occurs with rose red diaspore at Chester, Mass.

CORUNDOPHILITE, $At_4Sp \dots\dots At_7Sp_3$.

Green, more or less six sided plates. Resembles clinochlore. Occurs with corundum at Chester, Mass., and Asheville, N. C.

Prochlorite, (Chlorite and ripidolite in part), $\text{At}_7\text{Sp}_3 \dots \text{At}_3\text{Sp}_2$.

Monoclinic, prismatic class. Crystals are not well developed. Usually as six sided plates and scales, often arranged in divergent, fan shaped, or spheroidal groups. Occurs also massive, foliated, or granular. Sometimes as a scaly or dusty coating on, or disseminated through, quartz, titanite, periclinc, adularia, and so forth.

Perfect basal cleavage. Laminae are flexible and inelastic. Hardness 1. Specific gravity 2.8 to 2.95. Translucent to opaque. Very thin laminae may be transparent. Pearly luster on cleavage surfaces. Various shades of green in color. Slightly pleochroic.

Chemically, prochlorite is considered a mixture of the amesite and serpentine molecules, as indicated above. Usually contains about 27% of SiO_2 . Almost infusible, yields a black glass. Decomposed by concentrated acids.

Prochlorite is a very essential constituent of many chlorite schists, especially those containing magnetite. Occurs in serpentine, granite, gneiss, and so forth. It is a common alteration product of augite, hornblende, garnet, calcite, and also perhaps quartz and feldspar.

Clinochlore, ripidolite in part, $\text{At}_3\text{Sp}_2 \dots \text{AtSp}$.

Monoclinic, prismatic class. Usually in hexagonal pyramidal, tabular rhombohedral, or distinct monoclinic crystals. Sometimes bent and twisted. Twins according to the mica and penninite laws. In the latter case the basal pinacoid acts as the twinning plane. Coarse scaly granular, fine granular, and earthy. Massive.

Perfect basal cleavage. Laminae are tough, flexible, and but slightly elastic. Hardness 2. Specific gravity 2.55 to 2.8. Translucent to transparent. Pearly luster on the basal pinacoid, elsewhere vitreous to resinous. Various shades of green in color, usually bluish to blackish green.

Chemical composition as indicated. Contains about 30% of SiO_2 . Fuses with difficulty to a grayish yellow glass. Decomposed by sulphuric acid.

An important constituent of chlorite schists. Occurs also in talcose schists and rocks, and in serpentine. Often associated with garnet, diopside, magnesite, and apatite. Some localities are: Achmotovsk, Ural Mountains; Zillerthal, Pfitschthal, and Pfunders, Tyrol; Zermatt, Switzerland; Marienberg, Saxony; Westchester and Unionville, Pa.; Brewster, N. Y.

Penninite, $\text{AtSp} \dots \text{At}_2\text{Sp}_3$.

Monoclinic, prismatic class. $a : b : c = 0.5774 : 1 : 0.8531$, $\beta = 117^\circ 9'$. Crystals have a distinctly rhombohedral habit. The pyramidal faces are often striated horizontally and appear as steep rhombohedrons, truncated by the basal pinacoid. These crystals are usually trillings according to the mica law. Massive, consisting of an aggregate of scales; cryptocrystalline.

Perfect basal cleavage. Flexible. Hardness 2.5. Specific gravity 2.6 to 2.85. Transparent to translucent. Pearly luster on cleavage surfaces, elsewhere vitreous. Various shades of green, violet, red, pink, rose red, grayish red, yellowish, and silver white in color.

Chemical composition as indicated above. Contains about 33% of SiO_2 . Exfoliates and fuses with difficulty to a yellowish glass. Decomposed by acids.

Is not as common as clinochlore. Commonly an alteration product of biotite, amphibole, garnet, and feldspar. It is found in veins and cavities in various types of rocks, especially chlorite schists. Some localities are: Bin-nenthal, Pfischthal, Zermatt, and elsewhere, Switzerland; Magnet Cove, Ark.

ORTHOCHLORITES AND LEPTOCHLORITES.

Chloritic minerals are sometimes divided into two groups, *orthochlorites* and *leptochlorites*. The minerals, just described, are classified as orthochlorites. They occur usually in crystals or comparatively large lamella. The leptochlorites include closely related substances, occurring in aggregates or microscopic scaly masses. Their chemical composition is more or less doubtful. Orthochlorites are not easily decomposed by hydrochloric acid and do not yield much water below 500° ; leptochlorites on the other hand are readily decomposed and yield much water.

The leptochlorites include *daphanite*, *chamosite*, *metachlorite*, *clementite*, *thuringite*, *cronstedite*, *euralite*, *strigovite*, *diabantite*, *aphrosiderite*, *dellessite*, and *rumpfite*. These are known too imperfectly to warrant detailed descriptions.

SERPENTINE AND TALC GROUP

Here are placed certain basic magnesium silicates which are somewhat closely related to the chlorites. They may contain either iron or nickel, and yield water on ignition. They differ from the chlorites in that they do not contain aluminium. All are secondary minerals resulting from the decomposition of magnesium silicates containing little or no aluminium. Since they never occur in crystals but always in scaly and fibrous aggregates or compact, apparently amorphous, masses, their crystallographic nature and chemical composition are somewhat uncertain. This is not an isomorphous group.

SERPENTINE,	$\text{H}_4\text{Mg}_3\text{Si}_2\text{O}_9$.
TALC,	$\text{H}_2\text{Mg}_3\text{Si}_4\text{O}_{12}$.
Sepiolite,	$\text{H}_4\text{Mg}_2\text{Si}_3\text{O}_{10}$.
Garnierite,	$\text{H}_2(\text{Ni}, \text{Mg})\text{SiO}_4$.
DEWEYLITE,	$\text{H}_{12}\text{Mg}_4\text{Si}_3\text{O}_{16}$.
GENTHITE,	$\text{H}_{12}\text{Mg}_2\text{Ni}_2\text{Si}_3\text{O}_{16}$.

Saponite, a silicate of magnesium and aluminium with a variable composition, is also placed in this group.

SERPENTINE, $H_4Mg_3Si_2O_{10}$.

Orthorhombic or monoclinic. Never in crystals. Usually compact and massive with a microscopically fine fibrous or foliated structure. Sometimes more or less columnar or fibrous, or lamellar and foliated.

Conchoidal to splintery fracture. Smooth to greasy feel. Dull resinous, greasy, or waxy luster. Takes an excellent polish. Translucent to opaque. Hardness 2.5 to 4. Specific gravity 2.5 to 2.8. Various shades of green in color, also yellowish, grayish, reddish, brownish, or black. Specimens are often multi-colored. White streak.

According to Weinschenk, there are two distinct modifications of serpentine, *chrysotile* and *antigorite*. Groth considers antigorite and chrysotile as isomeric modifications. Antigorite is closely related to the chlorites.

Chrysotile. This is the more common modification and is characterized by its fibrous structure. It occurs in several varieties.

(1) *Common serpentine.* Compact, massive. Generally dark in color. Often multi-colored. Sometimes impure. Very abundant.

(2) *Precious serpentine.* Massive, more or less homogeneous. Various shades of green in color, sometimes yellowish. Translucent.

(3) *Fibrous serpentine, asbestos.* Consists of delicate, fine, parallel fibers, which can be easily separated. Fibers are flexible and adapted for spinning. Silky to silky metallic luster. Various shades of green in color, also yellowish and brownish. Usually found in narrow veins. The fibers extend across the veins. Sometimes called *short fibered asbestos*.

(4) *Verd-antique, ophicalite.* Massive green serpentine mixed irregularly with white calcite, dolomite, or magnesite. Takes an excellent polish and is used extensively for ornamental purposes. Polished serpentine is often termed *serpentine marble*.

Antigorite. A lamellar or foliated structure is characteristic for this modification. Generally in scaly or foliated aggregates. Dark green in color. Translucent. Contains a small amount of Al_2O_3 .

$H_4Mg_3Si_2O_{10}$. Usually contains some FeO, sometimes also NiO. Yields about 13% of water upon ignition. Splinters fuse with great difficulty. Slightly colored varieties turn pale red when treated with cobalt nitrate solution. Decomposed by acids with a separation of silica. May alter to brucite, magnesite, hydromagnesite, and webskyite ($H_6Mg_4Si_3O_{13} \cdot 6H_2O$).

Serpentine is a secondary mineral resulting from the decomposition of magnesium minerals and rocks, such as, olivine, enstatite, hornblende, augite, chondrodite, peridotite, and lherzolite. Olivine is the most common source of serpentine, the scales or fibers of serpentine coating the exterior

and extending along cracks into the interior of the crystal. The common associates are garnierite, chromite, pyrope, magnesite, platinum, and talc.

Serpentine occurs in many localities. In the United States it is mined in Chester County, Pa., and also at Easton, Pa. It is found at Hoboken and Montville, N. J.; Syracuse, N. Y.; Stevens County, Wash.; Milford, Conn. Asbestos is not found to any extent in the United States. Most of the asbestos of commerce is obtained from the mines in the Thetford-Black Lake district, Quebec, Canada.

Polished massive serpentine and verd-antique are used for ornamental and interior decorative purposes. Asbestos is used extensively in the manufacture of non-conductors of heat and incombustible materials such as, cloth, boards, felt, rope, paper, paint, cement, and theater curtains.

TALC, Soapstone, Steatite, $\text{H}_2\text{Mg}_3\text{Si}_4\text{O}_{12}$.

Monoclinic, on account of striking resemblances to the micas and chlorites. Distinct crystals have not been observed. Individual scales sometimes have an hexagonal or orthorhombic outline. Usually as foliated masses, globular and stellate groups, and sometimes fibrous, granular, and compact.

Perfect basal cleavage. Laminae are flexible but inelastic, and possess a pearly luster. Compact talc has an uneven to splintery fracture. Greasy feel. Hardness 1 to 2.5. Specific gravity 2.6 to 2.8. Translucent to transparent. White to green, gray, yellowish, reddish, and brown. Percussion figures are similar in outline and orientation to those of mica.

There are several varieties of talc:

(1) *Foliated talc*. Consists of small, easily separable folia. Soapy, greasy feel. Hardness 1, easily impressed by the finger nail. Light green to white in color.

(2) *Steatite or soapstone*. Massive. More or less impure. Coarse to fine granular, also schistose. Gray to greenish in color. Hardness 1.5 to 2.5. Occurs in large deposits.

(3) *French chalk*. Soft, compact, whitish masses. Marks cloth.

(4) *Rensselaerite*. Pseudomorphous. Altered from pyroxene. Wax-like masses. Hardness 3 to 4.

$\text{H}_2\text{Mg}_3\text{Si}_4\text{O}_{12}$. Magnesium oxide may be replaced by 1 to 5% of FeO . Small amounts of nickel and aluminium may be present also. When strongly ignited, yields water, hardens, and becomes susceptible to polish. Practically infusible, fuses with great difficulty on very thin edges. Turns white. Soapstone is but slightly decomposed by salt of phosphorous, while foliated talc becomes pink when treated with cobalt nitrate solution.

Talc is generally considered an alteration product of non-aluminous magnesium minerals, such as the pyroxenes and amphiboles, and olivine. It is

doubtful whether talc is ever a primary mineral. It occurs pseudomorphous after many minerals, for example, after pyroxene, hornblende, enstatite, tremolite, spinel, mica, scapolite, quartz, dolomite, topaz, staurolite, cyanite, garnet, vesuvianite, and chrysolite. Commonly found in metamorphic rocks, such as chloritic schists; also with serpentine and dolomite. Frequently occurs as talcose schist containing doubly terminated crystals of magnetite, dolomite, breunnerite, apatite, tourmaline, pyrite, and actinolite.

Foliated talc occurs at Greiner in the Zillerthal, Tyrol; various places in Switzerland, Italy, France, and Germany; at Grafton, and elsewhere, N. H.; Smithfield, R. I.; various places in St. Lawrence County, N. Y. The most important producing locality in the United States for talc and soapstone is Gouverneur, St. Lawrence County, N. Y., where talc occurs in connection with limestone, and has been derived from tremolite and enstatite. The Albemarle-Nelson County belt in Virginia, Montgomery and Northampton counties, Pa., and Phillipsburg, N. J., also produce large quantities of talc and soapstone annually. Other producing states are North Carolina, Georgia, Maryland, Rhode Island, and Massachusetts. In 1908 there were mined 117,354 tons, valued at \$1,401,222.

Talc and soapstone are used, when cut into slabs and other shapes, for washtubs, sanitary appliances, laboratory tables and tanks, electrical switchboards, mantels, hearthstones, fire-brick, kiln linings, foot warmers, slate pencils, crayon for marking iron, glass, and fabrics; when ground, in the manufacture of paper and dynamite, as pigment in paint, non-conductor of heat, lubricant, also for polishing glass, and for dressing skins and leather. It also enters into the composition of some soaps and toilet powders. Has been used to a small extent as an adulterant of sugar, baking powder, and flour.

Sepiolite, Meerschaum, $H_4Mg_2Si_3O_{10}$.

Crystallization unknown, sometimes thought to be monoclinic. Compact, earthy or clayey masses. Rarely fibrous. Smooth feel. Impressed by the finger nail. Hardness 2 to 2.5. Specific gravity 1 to 2. On account of its porosity, floats on water. Adheres to the tongue. Dull luster. Shiny streak. Conchoidal to uneven fracture. Opaque. White to yellowish, grayish, reddish, or greenish in color. When moist, grayish, soapy, and quite soft.

$H_4Mg_2Si_3O_{10}$. A variety from Utah contains 6.82% of CuO. Yields much water when strongly ignited. Due to the presence of hygroscopic water, more may be obtained than indicated in the formula. Fuses with difficulty on the thin edges to a white glass, some varieties first turn black. Turns pink when treated with cobalt nitrate solution. Gelatinizes with hydrochloric acid.

Usually considered an alteration product of serpentine, or possibly of

magnesite or of an impure opal containing considerable magnesium. It is found principally in nodular masses in serpentine or secondary deposits at the plains of Eskishehr, Asia Minor. Occurs in smaller quantities on some of the islands of the Grecian Archipelago, in Morocco, Moravia, and Utah.

Meerschaum is easily carved and worked on the lathe, takes an excellent polish, and is used extensively for pipe bowls and cigar tips. Asia Minor furnishes practically all of the meerschaum of commerce.

Garnierite, Noumeite, $H_2(Ni,Mg)SiO_4$.

Doubly refractive, but crystal system undetermined. Generally as compact, earthy masses; apparently amorphous. Easily broken. Also stalactitic and reniform. Apple to emerald green in color. Dull to greasy luster. Sometimes with varnish-like surfaces. Greasy feel. White to greenish streak. Opaque. Conchoidal fracture. Hardness 2 to 3. Specific gravity 2.3 to 2.8.

The composition varies greatly, contains from 35 to 47% of NiO. Infusible, decrepitates, and becomes magnetic. Yields water on ignition. Attacked by acids. Reacts for nickel.

An alteration product of olivine and serpentine rocks. Associated with chromite and talc, it occurs in large quantities in serpentine at Noumea, New Caledonia. Is also found at Frankenstein, Silesia; Webster, N. C.; Riddles, Douglas County, Oregon.

It is a valuable ore of nickel.

DEWEYLITE, Gymnite, $H_{12}Mg_4Si_3O_{16}$.

Apparently amorphous masses, resembling resin or gum arabic. Contains many cracks. Greasy luster. Imperfect conchoidal fracture. Translucent to transparent. White to yellow, also reddish, greenish, and rarely scarlet red. Hardness 2 to 3. Specific gravity 2 to 2.3.

When ignited yields much water. Formula is often written $Mg_4Si_3O_{10} + 6H_2O$. Decrepitates, becomes opaque, and fuses with difficulty on thin edges. Slowly decomposed by hydrochloric acid.

Occurs in serpentine at Bare Hills, Md.; Texas, Lancaster County, Pa.; Fleimsthal, Tyrol; Passau, Bavaria.

GENTHITE, Nickel gymnite, $H_{12}Mg_2Ni_2Si_3O_{16}$.

Very similar to deweyite but contains about 30% of NiO. Compact, minutely globular, reniform, or stalactitic; also as earthy masses. Green to yellow in color. Resinous luster. Conchoidal fracture. Hardness 3 to 4; may be softer. Specific gravity 2.4. Translucent to opaque. Infusible. Decomposed by hydrochloric acid without gelatinizing. Has been termed *nickel-sepiolite*. Is an alteration product of serpentine. Occurs on chromite at Texas, Lancaster County, Pa., and Alt-Orsova, Hungary; with serpentine at Webster, Jackson County, N. C.

SAPONITE is a silicate of magnesium and aluminium, yielding water on ignition. Composition is not constant. Nodular and massive. White, gray, yellowish, reddish, brown, and also greenish. Greasy luster and feel. Does not adhere to the tongue. Soft, can be cut with a knife. Hardness about 1. Becomes brittle when dry. Specific gravity 2.7. Blackens and fuses with difficulty on thin edges. Decomposed by sulphuric acid. Occurs in serpentine at Lizard Point, Cornwall, England; in dolerite near Dunbarton and Glasgow, Scotland; various places in Sweden.

KAOLINITE GROUP

The members of this group are silicates of aluminium yielding water on ignition. They correspond to the magnesian minerals, antigorite (serpentine) and talc in chemical composition and, like them, show some resemblances to the micas.

ANTIGORITE, $\text{H}_4\text{Mg}_3\text{Si}_2\text{O}_9$.

(Serpentine)

TALC, $\text{H}_2\text{Mg}_3\text{Si}_4\text{O}_{12}$.

KAOLINITE, $\text{H}_4\text{Al}_2\text{Si}_2\text{O}_9$.

NONTRONITE, $\text{H}_4\text{Fe}_2\text{Si}_2\text{O}_9$.

PYROPHYLLITE, $\text{H}_2\text{Al}_2\text{Si}_4\text{O}_{12}$.

The three atoms of magnesium in antigorite and talc are replaced by two of aluminium having the same valency. Kaolinite is the most important member of this group.

KAOLINITE, Kaolin, China Clay, $\text{H}_4\text{Al}_2\text{Si}_2\text{O}_9$.

Monoclinic, prismatic class. $a : b : c = 0.5748 : 1 : 1.5997$, $\beta = 96^\circ 49'$. Generally as compact, friable, or mealy clay-like masses. Rarely in small scales with an hexagonal or orthorhombic outline.

Scales possess a perfect basal cleavage. Laminae are flexible but not elastic. Subconchoidal to earthy fracture. Hardness 1 or higher. Specific gravity 2.2 to 2.6. Scales possess a pearly luster, compact masses are dull. White, yellowish, reddish, bluish, greenish, or brownish in color. Scales may be translucent, masses opaque. Greasy feel. White to yellowish streak. Usually adheres to the tongue and becomes plastic when moistened with water. Argillaceous odor. The older terms *nacrite* and *pholerite* refer to certain crystalline and compact varieties. The compact variety of great commercial importance is called *kaolin* or *china clay*.

$\text{H}_4\text{Al}_2\text{Si}_2\text{O}_9$. Yields water on ignition. Infusible. Partially decomposed by hydrochloric acid, completely by concentrated sulphuric acid. Turns blue when treated with cobalt nitrate solution.

Kaolinite is always a secondary mineral, the result of the action of post-volcanic, pneumatolytic and hydrothermal processes upon rocks containing feldspar, nephelite, topaz, beryl, augite, scapolite, and other aluminium minerals. It is sometimes considered as being formed by ordinary weathering. Occurs often as a pseudomorph after these minerals. May be found in irregular beds in *kaolinized* granites, porphyries, and gneisses, and is then mixed with quartz. Also in secondary deposits, the results of transportation and deposition under water. Occurrences of the second type may be very impure. Commonly noted also with ore deposits, especially those of tin, lead, and zinc. Some localities are: St. Yrieix, near Limoges, France; Corn-

wall and Devonshire, England; Meissen, Saxony. In the United States kaolin is mined in Chester and Delaware counties, Pa.; also at various places in North Carolina, Connecticut, Maryland, Virginia, Ohio, and New Jersey. North Carolina and Pennsylvania are the largest producers.

Kaolin is used in large quantities in the manufacture of china-ware, porcelain, tiles, and other refractory materials. 28,649 tons of kaolin, valued at \$216,243, were mined in 1908.

NONTRONITE, $H_4Fe_2Si_2O_9$.

Monoclinic. Compact massive, earthy, and apparently amorphous. Soft. Specific gravity 2. Often with a greasy feel. Yellowish green to green in color. Dull luster. Uneven fracture. Opaque. Infusible, changes color, and becomes magnetic. Completely decomposed by acids and potassium hydroxide. Occurs with limonite at Nontron, France; St. Andreasberg and Tirschenreuth, Saxony. *Choropal* is green nontronite mixed with opal.

PYROPHYLLITE, Pencil Stone, $H_2Al_2Si_4O_{12}$.

Orthorhombic, but may be monoclinic. Columnar, radial, or stellate aggregates of foliae or fibres; also granular to compact or cryptocrystalline. A compact variety is called *agalmatolite* or *pencil stone*.

Perfect cleavage parallel to the length of the fibers. Laminae flexible, but not elastic. Greasy feel. Hardness 1. Specific gravity 2.8 to 2.9. Pearly luster. Translucent. Apple green, white, brownish, or yellowish in color. Looks like talc.

$H_2Al_2Si_4O_{12}$. Exfoliates and yields water at a high temperature. Turns white and fuses on the edges. Turns blue when treated with cobalt nitrate solution. Partially decomposed by sulphuric acid. Alters to kaolinite.

Occurs in schistose rocks in the Ural mountains, Sweden, and Brazil. In the United States pyrophyllite occurs at Graves Mountain, Ga.; Deep River, N. C.; Chesterfield, S. C.; Mahanoy City, Schuylkill County, Pa.

Compact pyrophyllite is used for slate pencils, agalmatolite for ornamental carvings.

NEPHELITE GROUP

The members of this group are rather complex silicates of aluminium and the alkalis, and although they are not isomorphous, their chemical composition is similar.

NEPHELITE, $(Na,K)_8Al_8Si_9O_{34}$.

Cancrinite, $H_4(Na_{22}Ca)_4(NaCO_3)_2Al_8Si_9O_{36}$.

DAVYNE, $(Na_2,Ca,K_2)_{16}(NaCO_3,NaSO_4,Cl)_{11}Al_{25}Si_{24}O_{96}$.

Nephelite is the most common mineral of the group. It crystallizes in the hexagonal pyramidal class, while cancrinite and davyne have both been referred to the dihexagonal bipyramidal class.

NEPHELITE, Nepheline, Elaeolite, $(\text{Na}, \text{K})_8\text{Al}_8\text{Si}_9\text{O}_{34}$.

Hexagonal, pyramidal class. $a : c = 1 : 0.8383$. Crystals are short prismatic or tabular, and apparently holohedral. Hemimorphism is revealed by etch figures. The forms generally observed are the prisms of the first and second orders, the corresponding, apparently holohedral, bipyramids, and the basal pinacoids. Occurs also compact, massive, and as disseminated grains.

Imperfect prismatic and basal cleavages. Conchoidal to uneven fractures. Brittle. Characteristic greasy luster on cleavages, elsewhere vitreous. Hardness 5 to 6. Specific gravity 2.55 to 2.65. Colorless, white, yellowish, greenish, gray, brownish red, or red in color. Uncolored streak.

There are two varieties:

Nephelite proper. Colorless, white, or gray, glassy occurrences, showing in many instances definite crystal outline. Common in the more recent eruptive rocks. Transparent to translucent.

Elaeolite. Massive and granular, rarely with a definite outline. More highly colored,—green, red, gray, brown, or blue. Cloudy or opaque. Greasy luster. Contains many microscopic, needle-like inclusions. Common and present often in considerable quantities in the older plutonic rocks, such as syenites, phonolites, and basalts. Nepheline-syenite contains a comparatively large amount of elaeolite.

$(\text{Na}, \text{K})_8\text{Al}_8\text{Si}_9\text{O}_{34}$. The composition varies greatly. The best analyses point to the formula given, although it is often thought that the composition ought to be expressed by the simple formula NaAlSiO_4 , the composition of synthetic soda-nephelite. Potassium is always present as follows: $\text{Na} : \text{K} = (3 \text{ to } 5) : 1$. Traces of chlorine are always noted. *Eucryptite* is lithium-nephelite, while *kaliophilite* or *phacelite* are terms applied to potassium-nephelite. Gelatinizes easily and rapidly with hydrochloric acid; on evaporation to dryness cubes of NaCl form. Fuses quite easily to a colorless glass. Alters easily and forms hydronephelite, sodalite, muscovite, cancrinite, analcite, kaolinite, or garnet.

Nephelite is commonly associated with feldspar, cancrinite, biotite, sodalite, and zircon. May occur pseudomorphous after leucite. Some localities are: Mount Vesuvius; Katzenbuckel, Baden; Laacher See, Rhenish Prussia; Sweden; Portugal; Ural Mountains; Brazil; Montreal, and Dungannon township, Ontario, Canada. In the United States at Litchfield, Me.; Salem, Mass.; Beemersville, N. J.; Austin, Tex.; Magnet Cove, Ark.

Cancrinite, $H_3(Na_2, Ca)_4(NaCO_3)_2Al_3Si_9O_{36}$.

Hexagonal, dihexagonal bipyramidal class (?). $a : c = 1 : 0.4409$. Crystals are columnar, but rare. Usually in compact, lamellar or columnar masses.

Perfect prismatic cleavage. Uneven fracture. Pearly luster on cleavages, elsewhere vitreous to greasy. Transparent to translucent. Usually colored, lemon to brownish yellow, reddish, gray, green, or white; more rarely blue or colorless. Uncolored streak. Hardness 5 to 6. Specific gravity 2.45. Fuses easily with intumescence and loss of color to a white blebby glass. Upon ignition turns white and yields water. Effervesces with hydrochloric acid, and gelatinizes on heating.

Cancrinite may be a primary constituent of igneous rocks, although in most cases it is a secondary formation, the result of the alteration of nephelite. It occurs in nephelite-syenites at Barkevik, Norway; Miask, Ural Mountains; Finland; Särna, Sweden; Ditró, Hungary; Montreal and Beloeil, Province of Quebec, Canada; Litchfield and Gardiner, Me. It is usually associated with elaeolite, sodalite, feldspar, titanite, and apatite.

DAVYNE, Microsomite, $(Na_2, Ca, K_2)_{16}(NaCO_3, NaSO_4, Cl)_{11}Al_{25}Si_{24}O_{98}$.

Hexagonal, dihexagonal bipyramidal class. $a : c = 1 : 0.4183$. Slender columnar to needle-like crystals. Milky vitreous to pearly luster. Transparent to opaque. Colorless, white, or wine yellow. Perfect prismatic cleavage. Conchoidal to uneven fracture. Hardness 5 to 6. Specific gravity 2.4. Easily fusible with intumescence to a white blebby glass. Fresh crystals do not yield water on ignition. Easily soluble in acids with a faint, but distinct odor of hydrogen sulphide. Occurs in the cavities of the lavas and as a sublimation product on Mount Vesuvius.

SODALITE GROUP

The members of this group crystallize in the cubic system, and undoubtedly in the hextetrahedral class, based upon observations on sodalite. Chemically, they are acid orthosilicates of sodium, aluminium, and calcium, and contain radicals with chlorine and sulphur, which are not often present in silicates.

Sodalite, $Na_4Al_2(AlCl)(SiO_4)_3$.

NOSELITE, $Na_4Al_2[Al(NaSO_4)](SiO_4)_3$.

HAÜYNITE, $Na_2CaAl_2[Al(NaSO_4)](SiO_4)_3$.

Lazurite, $(Na_2, Ca)_2Al_2[Al(NaSO_4, NaS_3, Cl)](SiO_4)_3$.

These are closely related in many ways to those of the nephelite group. Brögger has shown that there is also a similarity to the garnets, see page 208.

Sodalite, $Na_4Al_2(AlCl)(SiO_4)_3$.

Cubic, hextetrahedral class. Rhombic dodecahedral habit is common. The forms generally observed are the rhombic dodecahedron, cube, octahedron, and the tetragonal trisoctahedron ($m=2$). Crystals are apparently

holohedral in development, but the lower symmetry is revealed by etch figures. Twins, according to the spinel law, are generally elongated parallel to a trigonal axis of symmetry. Occurs for the most part massive, in grains, cleavable aggregates, and concentric nodules.

Distinct dodecahedral cleavage. Uneven to conchoidal fracture. Brittle. Hardness 5 to 6. Specific gravity 2.2 to 2.4. Vitreous luster on crystal faces, greasy on cleavages. Generally translucent, but may be transparent to opaque. Colorless, white, gray, light to dark blue, greenish, or reddish. White streak.

$\text{Na}_4\text{Al}_2(\text{AlCl})(\text{SiO}_4)_3$. The formula is sometimes written $3\text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8 + 2\text{NaCl}$. Colored varieties turn white when heated. Fuses with intumescence to a colorless glass. NaCl may be extracted by digesting the finely powdered mineral with water. Gelatinizes with hydrochloric acid. May contain many microscopic inclusions. Is sometimes an alteration product of nephelite.

Occurs commonly associated with elaeolite and cancrinite. Some localities are: Ditro, Transylvania; Miask, Ural Mountains; Mount Vesuvius; Serra de Monchique, Portugal; Langesundfjord, Norway; Montreal and Beloeil, Quebec, and Dungannon, Ontario, Canada; Litchfield, Me.; Salem, Mass.; Crazy Mountains and elsewhere, Mont.

NOSELITE, Nosean, $\text{Na}_4\text{Al}_2[\text{Al}(\text{NaSO}_4)](\text{SiO}_4)_3$.

Cubic. Dodecahedral crystals and irregular grains. Very similar to h  yynite, differing from it principally by the absence of calcium. Gray, bluish, or red. Vitreous luster. Hardness 5 to 6. Specific gravity 2.25. Occurs only in volcanic rocks, especially phonolites. Thus, in the Laacher See district, near the Rhine, Germany; and Hohentwiel, Baden; Canary and Cape Verde Islands.

HA  YNYTE, H  y  ne, $\text{Na}_2\text{CaAl}_2[\text{Al}(\text{NaSO}_4)](\text{SiO}_4)_3$.

Cubic. Sometimes in dodecahedral or octahedral crystals. The faces may appear to be more or less fused. Penetration and polysynthetic twins according to the spinel law. Commonly in rounded grains.

Distinct dodecahedral cleavage. Conchoidal to uneven fracture. Hardness 5 to 6. Specific gravity 2.3 to 2.5. Vitreous to greasy luster. Translucent to opaque. Mostly blue in color; also green, red, or black; rarely colorless. Bluish to colorless streak.

$\text{Na}_2\text{CaAl}_2[\text{Al}(\text{NaSO}_4)](\text{SiO}_4)_3$. The formula is also written $3(\text{Na}_2\text{Ca})\text{Al}_2\text{Si}_2\text{O}_8 + 2(\text{Na}_2\text{Ca})\text{SO}_4$. Fuses with difficulty to a white glass. Reacts for sulphur. Decomposed by hydrochloric acid, yielding gelatinous silica.

Nephelite and leucite are common associates. It occurs only in volcanic rocks, especially phonolites and related rocks. Some localities are: the lavas of Mount Vesuvius and vicinity; in the phonolite of the Hohentwiel, Baden; in the Eifel, west of the Rhine, Germany.

Lazurite, Lasurite, Lapis-Lazuli, Native Ultramarine,

$(\text{Na}_{2-2}\text{Ca})_2\text{Al}_2[\text{Al}(\text{NaSO}_4, \text{NaS}_3, \text{Cl})](\text{SiO}_4)_3$.

Cubic. Dodecahedral or octahedral crystals are rare. Usually as irregular grains, or massive containing disseminated pyrite.

Imperfect dodecahedral cleavage. Uneven fracture. Hardness 5 to

5.5. Specific gravity 2.4. Vitreous to greasy luster. Deep to azure blue in color, sometimes violet to greenish blue. White streak. Opaque to translucent.

The mineral is essentially an isomorphous mixture, consisting of about 75% of h  ynite, 9% of sodalite, and 16% of natural ultramarine with the composition $3\text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8 + 2\text{Na}_2\text{S}_3$. Fuses easily to a white blebby glass. Gelatinizes with HCl, loses color, and evolves an odor of hydrogen sulphide.

Lazulite is a contact mineral and occurs in crystalline limestones. The principal localities are in central Asia at Badakschau and the southern end of Lake Baikal; occurs also in Chile and in the ejected masses on Mount Vesuvius.

Highly valued for ornaments, mosaics, and vases. Formerly, it was used as a pigment in oil painting.

Several comparatively rare silicates of lead, barium, and yttrium may be placed here.

GANOMALITE, $\text{Pb}_4(\text{PbOH})_2\text{Ca}_4(\text{Si}_2\text{O}_7)_3$.

Tetragonal. $a : c = 1 : 0.35$, approximately. Long, prismatic crystals; but usually massive and granular, resembling granular tephorite. Distinct basal and prismatic cleavages. Greasy vitreous luster. Colorless to gray, oxidizes on exposure and turns white and dull. Very brittle. Hardness 3 to 4. Specific gravity 5.74. Reddish streak. Fuses in the candle flame. Soluble in nitric acid. Found at L  ngban and Jakobsberg, Sweden.

NASONITE, $\text{Pb}_4(\text{PbCl})_2\text{Ca}_4(\text{Si}_2\text{O}_7)_3$. Very similar to ganomalite. Contains about 3.5% of chlorine replacing the hydroxyl. Compact. White. Greasy luster. Hardness 4. Specific gravity 5.425. Occurs at Franklin Furnace, N. J.

BARYSILITE, $\text{Pb}_3\text{Si}_2\text{O}_7$.

Hexagonal. $a : c = 1 : 0.4863$. Crystals are rhombohedral and tabular in habit; also in curved foliated masses. Distinct basal cleavage. Silver white color, often tarnished. Fuses in the flame of a candle. Easily decomposed by acids. Hardness 3. Specific gravity 6.72. Found in the Hartsig mine, Pajsberg, Sweden.

HARDYSTONITE, $\text{Ca}_2\text{ZnSi}_2\text{O}_7$.

Tetragonal. Granular masses with basal and prismatic cleavages. Hardness 3 to 4. Specific gravity 3.4. Color white. Vitreous luster. Fuses with difficulty to a cloudy glass, coloring the flame red. Reacts for zinc. Gelatinizes with hydrochloric acid. Occurs with willemite, rhodonite, and franklinite in the North Hill mine, Franklin Furnace, N. J.

BARYLITE, $\text{Ba}_4\text{Al}_4\text{Si}_7\text{O}_{24}$.

Orthorhombic (?). Compact aggregates; prismatic crystals are rare. Hardness 7. Specific gravity 4. Greasy luster. Colorless. Semi-transparent. Infusible. Not acted upon by acids. Occurs as a metamorphic mineral in crystalline limestone at L  ngban, Sweden.

Iolite, Cordierite, Dichroite, $(\text{Mg,Fe})_4\text{Al}_8(\text{OH})_2(\text{Si}_2\text{O}_7)_5$.

Orthorhombic, bipyramidal class. $a : b : c = 0.5870 : 1 : 0.5585$. Crystals are usually short prismatic with six or twelve sides, hence, pseudo-hexagonal. The prism angle is $119^\circ 10'$. The faces are often dull and the edges rounded. The common forms are the unit prism, brachyprism ($n=3$), and the three pinacoids. Penetration trillings and sixlings with the twinning plane parallel to the unit prism are sometimes observed. Occurs generally in irregular and rounded masses, resembling quartz.

Distinct brachypinacoidal cleavage, indistinct parallel to the other pinacoids. Conchoidal to uneven fracture. Hardness 7 to 7.5. Specific gravity 2.6 to 2.7. Vitreous to greasy luster. Transparent to subtransparent. Light to dark smoky blue; also gray, colorless, yellowish, green, brown, or violet. White streak. Very strong pleochroism which is sometimes easily noted, violet blue for vibrations parallel to the b axis, yellowish parallel to c , and grayish blue parallel to a .

$(\text{Mg,Fe})_4\text{Al}_8(\text{OH})_2(\text{Si}_2\text{O}_7)_5$. The iron is trivalent. Some calcium replaces magnesium. Fresh material yields water on ignition. Fuses with difficulty on the thin edges. Slightly acted on by acids. Iolite alters easily, taking up water and the alkalis, and losing SiO_2 and MgO . The end products are the micas and chlorites. Many of the intermediate substances formed have received such distinctive names as: chlorophyllite, praseolite, aspasiolite, gigantolite, fahlunite, pinite, pyrargillite, bonsdorffite, and esmarkite.

Iolite is found chiefly in gneiss and other crystalline schists and in contact metamorphic zones. Occurs also in granite, andesite, and dacite; also in rounded particles in secondary deposits. The common associates are quartz, orthoclase, albite, tourmaline, pyrrhotite, chalcopyrite, hornblende, andalusite, sillimanite, staurolite, spinel, garnet, zircon, and beryl. Some of the principal localities are: Bodenmais, Bavaria; Falun, Sweden; Kragerøe, Tvedestrand, and Bamle, Norway; Island of Elba; Laacher See, Rhenish Prussia; Cabo de Gato, Spain; Ceylon; Haddam, Conn.; Brimfield, Mass.; Richmond, N. H.

Transparent varieties from Ceylon are sometimes used for gem purpose.

MELILITE GROUP

According to Vogt, melilite is an isomorphous mixture of the two silicates âkermanite, which does not occur in nature but is found practically pure in basic calcereous slags, and gehlenite. The latter occurs as a mineral. The composition of these silicates is as follows:

ÂKERMANITE,	$\text{Ca}_3\text{CaSiSi}_2\text{O}_{10}$.
GEHLENITE,	$\text{Ca}_3\text{AlAlSi}_2\text{O}_{10}$.

In melilite these two silicates occur in about equal proportions, so that the composition may be expressed by merging the two formulas.

MELILITE, *Humboldtite*, *Sommervillite*, $\text{Ca}_7\text{Al}_2\text{Si}_4\text{O}_{20}$.

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.4548$. Small tabular, short prismatic, and rarely long columnar or needle-like crystals. The very common forms are the basal pinacoid, and the prism of the second order. The prism and bipyramid of the first order, and the ditetragonal prism, $n = 3$, are also observed. Occurs also in radial aggregates.

Distinct basal cleavage. Hardness 5 to 5.5. Specific gravity 2.9 to 3.1. Conchoidal to uneven fracture. Greasy luster on fracture surfaces, elsewhere vitreous. Yellow, brown, greenish, gray, and white in color. Translucent.

Is an isomorphous mixture, see introductory statement to this group. Some of the calcium may be replaced by magnesium and sodium, the aluminium by trivalent iron. Fuses to a yellowish or greenish glass. Gelatinizes with hydrochloric acid.

Occurs in basic eruptive rocks, especially those containing augite, nephelite, and leucite. Occurs in the lavas of Mount Vesuvius; Herchenberg, Rhenish Prussia; Löbau, Saxony; Finland; Mannheim and Syracuse, N. Y.; Uvalde County, Texas.

GEHLENITE, $\text{Ca}_3\text{Al}_2\text{Si}_2\text{O}_{10}$.

Tetragonal, ditetragonal bipyramidal class. $a : c = 1 : 0.4006$. Small, disseminated, short prismatic, or thick tabular crystals; also in loose aggregates. Distinct basal cleavage. Hardness 5.5 to 6. Specific gravity 3. Greasy luster. Translucent to opaque. Greenish gray to green or brown. Calcium and aluminium may be partially replaced by magnesium, and by ferrous and ferric iron. Fuses with difficulty. Gelatinizes easily with acids. Occurs in the contact zone in limestone at Monzoni and Predazzo, Tyrol, and artificially in slags.

ASTROPHYLLITE, $(\text{K}, \text{Na}, \text{H})_4(\text{Fe}, \text{Mn})_4(\text{Si}, \text{Ti})_5\text{O}_{16}$.

Orthorhombic, bipyramidal class. $a : b : c = 1.0098 : 1 : 4.7566$. Crystals often show apparently monoclinic or triclinic habits. Tabular, long radial, or bladed crystals; also in stellate groups. Basal cleavage. Brittle. Hardness 3 to 3.5. Specific gravity 3.3 to 3.4. Translucent. Distinct pleochroism. Vitreous to metallic luster. Bronze to gold yellow in color.

May contain small amounts of ZrO_2 , CaO , or MgO . Fuses easily to a black glass. Is oftentimes placed with the pyroxenes or chlorites. Occurs in elaeolite syenite in the Langesund fiord, near Brevik, Norway; Kangerdluarsuk and Narsarsuk, Greenland; Pike's Peak district, Colo.

PEROVSKITE-ILMENITE GROUP

The members of this group are metatitanates of calcium, magnesium, manganese, and iron. From the chemical standpoint they are very similar, but they do not all crystallize in the same system.

Perovskite, CaTiO_3.	Pseudo-cubic, probably orthorhombic.
GEIKIELITE, MgTiO_3.	Hexagonal, $a : c$ 1 : ?
PYROPHANITE, MnTiO_3.	Hexagonal, 1 : 1.369
Ilmenite, FeTiO_3.	Hexagonal, 1 : 1.385

Ilmenite is the most important member of the group and, on account of its similarity, chemically and crystallographically, with hematite, it is sometimes regarded as an oxide.

Hematite, $\text{Fe} \equiv \text{O}_3 \equiv \text{Fe}$, Ditrigonal Scalenohedral Class

Ilmenite, $\text{Fe} = \text{O}_3 \equiv \text{Ti}$, Trigonal Rhombohedral Class

Penfield and Foote have, however, shown that ilmenite is to be considered a metatitanate. The difference in the symmetry of the two formulas finds expression also in the crystals, those of ilmenite being of a lower grade.

Perovskite, Perowskite, CaTiO_3 .

Crystals are pseudo-cubical in habit, but are made up of polysynthetic twin lamellae. These are biaxial and probably orthorhombic. The relation between the external form and internal structure is somewhat similar to that of boracite and leucite, with the exception, however, that the lamellae do not disappear on heating. The forms commonly observed are the cube, octahedron, and rhombic dodecahedron; more rarely various tetragonal trisoctahedrons, tetrahexahedrons, and hexoctahedrons. The cube faces are often striated parallel to the edges, as in the case of pyrite, see page 39. Crystals are often highly modified. Etch figures indicate a lower grade of symmetry than that of the cubic system. Also in reniform masses or rounded grains.

Fairly distinct cubical cleavage. Uneven to subconchoidal fracture. Brittle. Hardness 5 to 6. Specific gravity 3.95 to 4.1. Adamantine to metallic luster. Transparent to opaque. Color black, grayish black, brownish black, reddish brown, or various shades of yellow. Colorless to gray streak.

CaTiO_3 . From 2 to 6% of FeO may replace CaO. *Knopite* is a variety from Alnö, Sweden, and contains from 6 to 7% of the cerium earths. Infusible. Scarcely attacked by hydrochloric acid; decomposed by hot sulphuric acid. Alters to ilmenite and magnetite.

Microscopic crystals occur in metamorphic rocks, such as talc and chlorite schists, but are not common. Rather common as a microscopic accessory mineral in young basic eruptive rocks, especially those containing melilite, leucite, and nephelite. Some localities are Achmatow mine, Zlatoust, Ural Mountains; Zermatt, Switzerland; Val Malenco, Italy; Pfäfers, Tyrol; near Montreal, Canada; Syracuse, N. Y.; Magnet Cove, Ark.; Elliott County, Kentucky.

GEIKIELITE, MgTiO_3 .

Hexagonal, perhaps trigonal rhombohedral class. Very rarely in small rhombohedral crystals, more commonly as rounded or irregular grains. Basal and rhombohedral cleavages. Bluish to brownish black in color, in transmitted light red. Metallic

luster. Black streak. Hardness 6. Specific gravity 4. Generally contains iron replacing some of the magnesium. Occurs in the precious stone placers of Rakwana, Ceylon.

PYROPHANITE, MnTiO_3 .

Hexagonal, probably trigonal rhombohedral class. Occurs in small tabular crystals with a blood red color and vitreous to submetallic luster in the Harstig mine, Sweden. Hardness 5. Specific gravity 4.5.

Ilmenite, Menaccanite, Titanic Iron Ore, Titaniferous Iron, FeTiO_3 .

Hexagonal, trigonal rhombohedral class. $a : c = 1 : 1.3846$. Crystals are tabular or rhombohedral in habit, and resemble those of hematite, page 86, but show rhombohedrons of the second and third orders. Crystals may be highly modified. Thirty-two forms have been recorded. There are two twinning laws, parallel to the basal pinacoid and the unit rhombohedron of the first order. Polysynthetic twinning is rather common parallel to the rhombohedron. Occurs also in thin plates, granular and compact masses, and as disseminated grains and sand.

No cleavage. Basal and rhombohedral partings. Conchoidal to uneven fracture. Submetallic to metallic luster, especially on fracture surfaces; otherwise dull. Opaque, thin plates are brown in transmitted light. Iron black to brownish black in color. Black to brownish red streak. Slightly magnetic, greatly increased by heating. Hardness 5 to 6. Specific gravity 4.3 to 5.5, increasing with the percentage of Fe_2O_3 present.

FeTiO_3 . Magnesium may replace some of the iron. *Picrotitanite*, or better termed *picroilmenite*, is a variety containing as high as 16% of MgO . Considerable Fe_2O_3 is sometimes present and such varieties, *washingtonite* and *hystatite*, pass gradually with an increase in trivalent iron into hematite. The proportion of Fe_2O_3 to FeTiO_3 may be expressed by the ratio, $\text{Fe}_2\text{O}_3 : \text{FeTiO}_3 = (1 \text{ to } 3) : (10 \text{ to } 1)$. Thin edges are slightly fused in the reducing flame, infusible in the oxidizing flame. Fused with sodium carbonate and treated with hydrochloric acid and tin foil, it reacts for titanium, the solution turning blue or violet. Decomposed by fusing with potassium bisulphate. Alters to a white, opaque titanite, called *leucoxene* or better *titanomorphite*, or to anatase, perovskite, rutile, limonite, or ferruginous carbonates.

Occurs widely distributed as an associate of hematite and magnetite. As an accessory mineral it is common in many igneous and metamorphic rocks, such as, granite, syenite, diorite, diabase, gneiss, mica schist, and so forth. In the fissures in these rocks, it is often found in large masses. As a coloring material it is sometimes present in microscopic particles, especially in labradorite and hypersthene. Also found in considerable quantities in black sands.

Some localities are: Ekersund, Snarum, Kragerö, Tvedestrand, and Hitterö, Norway; various places in Sweden; St. Gotthard district and Binnenthal, Switzerland; Zillerthal and elsewhere, Tyrol; Charlevoix, Montmorency, Beauce, and Montcalm counties, Quebec, Canada; various places in Orange County, especially Warwick, Amity, and Monroe, Conn.; South Roy-

alston and Chester, Mass.; Adamstown, Pa.; Magnet Cove, Ark.; Troy, Vt.

It is used in the preparation of linings for puddling furnaces. On account of the difficulty in reducing it, ilmenite is not used to any extent as an ore of iron.

PYROXENE GROUP

This group consists of metasilicates of calcium, magnesium, iron, aluminium, sodium, lithium, manganese, and zinc, corresponding to the general formula $M''_2(\text{SiO}_3)_2$. Although these minerals crystallize in three different systems—orthorhombic, monoclinic, and triclinic,—they form a well defined isomorphous group. Their elements of crystallization are very similar. All members are characterized by prism angles and cleavages of about 87° and 93° . Orthorhombic pyroxenes generally contain no calcium and little or no aluminium. The monoclinic members usually have considerable calcium and may, or may not, contain aluminium and the alkalis. In the triclinic series, manganese is an important constituent.

1. ORTHORHOMBIC SERIES

(Bipyramidal Class)

	a	b	c
Enstatite, $\text{Mg}_2(\text{SiO}_3)_2$.	1.0308	1	0.5885
Bronzite, $(\text{Mg}, \text{Fe})_2(\text{SiO}_3)_2$.			
Hypersthene, $(\text{Fe}, \text{Mg})_2(\text{SiO}_3)_2$.			
	1.0295	1	0.5868

2. MONOCLINIC SERIES

(Prismatic Class)

(a) Non-aluminous varieties:—

	a	b	c	β
DIOPSIDE, $\text{CaMg}(\text{SiO}_3)_2$.	1.0913	1	0.5895,	$105^\circ 51'$
(Malacolite, salite, diallage, etc.)				
HEDENBERGITE, $\text{CaFe}(\text{SiO}_3)_2$.	1.0912	1	0.5843,	$105^\circ 25'$
SCHEFFERITE, $(\text{Ca}, \text{Mg})(\text{Fe}, \text{Mn})(\text{SiO}_3)_2$.	1.0988	1	0.5953,	$105^\circ 25'$
JEFFERSONITE, $(\text{Ca}, \text{Mn})(\text{Mg}, \text{Fe}, \text{Zn})(\text{SiO}_3)_2$.			?	
Wollastonite, $\text{Ca}_2(\text{SiO}_3)_2$.	1.0531	1	0.9676,	$95^\circ 30'$

(b) Aluminous varieties:—

AUGITE,	$(\text{Mg,Fe})\text{Ca}(\text{SiO}_3)(\text{SiO}_3).$	1.0921	1	0.5893,	$105^\circ 40'$
	$(\text{Mg,Fe})\text{Al}(\text{AlO}_3)(\text{SiO}_3).$				
	$(\text{Mg,Fe})\text{Fe}(\text{FeO}_3)(\text{SiO}_3).$				
(Fassaite, leucaugite, etc.)					

(c) *Varieties containing alkalis*:—

	a	b	c	β
Pectolite , $(\text{Ca}, \text{Na}_2)_2(\text{SiO}_3)_2$.	1.1140	: 1	: 0.9864,	95° 20'
JADEITE , $\text{NaAl}(\text{SiO}_3)_2$.			?	
Spodumene , $\text{LiAl}(\text{SiO}_3)_2$.	1.1238	: 1	: 0.6355,	110° 20'
ACMITE , $\text{NaFe}(\text{SiO}_3)_2$.	1.0996	: 1	: 0.6012,	106° 49'
(Aegirite)				

3. TRICLINIC SERIES (Pinacoidal Class)

	a	b	c
Rhodonite , $\text{Mn}_2(\text{SiO}_3)_2$.	1.0728	: 1	: 0.6213
	$\alpha = 103^\circ 18'$,	$\beta = 108^\circ 44'$,	$\gamma = 81^\circ 39'$
FOWLERITE , $(\text{Mn}, \text{Fe}, \text{Ca}, \text{Zn}, \text{Mg})_2(\text{SiO}_3)_2$.	1.0780	: 1	: 0.6263
	$\alpha = 103^\circ 39'$,	$\beta = 108^\circ 48.5'$,	$\gamma = 81^\circ 55'$
BABINGTONITE , $\left\{ \begin{array}{l} (\text{Ca}, \text{Fe}, \text{Mn})_2(\text{SiO}_3)_2 \\ \text{Fe}_2(\text{SiO}_3)_2 \end{array} \right.$.	1.0691	: 1	: 0.6308
	$\alpha = 104^\circ 21\frac{1}{2}'$,	$\beta = 108^\circ 31'$,	$\gamma = 83^\circ 34'$

The members of the pyroxene group are important rock minerals. They are rather closely related, chemically and crystallographically, to the minerals of the amphibole group, page 250. This relationship will be discussed under the amphiboles.

ORTHORHOMBIC PYROXENES

Enstatite, $\text{Mg}_2(\text{SiO}_3)_2$.

Orthorhombic, bipyramidal class. $a : b : c = 1.0308 : 1 : 0.5885$. Distinct crystals are rare. They are prismatic in habit and usually consist of a combination of the unit prism, brachy- and macropinacoids, and brachydomes. Prism angle is about 92° . Generally found in fibrous, lamellar, or compact masses.

Distinct prismatic and indistinct brachy- and macropinacoidal cleavages. Brittle. Hardness 5.5. Specific gravity 3.1 to 3.3. Translucent to opaque. Silky or metallic luster, pearly on cleavages. Grayish white, yellowish, light to olive green, and brownish in color. Grayish or uncolored streak.

$\text{Mg}_2(\text{SiO}_3)_2$. May contain a small amount of iron, usually not over 5% of FeO. Slightly fusible on thin edges. Insoluble in acids. Alters to *bastite*—a fibrous aggregate with the composition of serpentine,—talc, and serpentine.

Enstatite is an essential constituent of certain pyroxenites, peridotites, norites, and the serpentines derived from them. Occurs in large crystals in an apatite vein at Kjörrestad, near Bamle, Norway; Aloysthal, Moravia; Kupferberg, Bavaria; in the diamondiferous blue ground of South Africa; Tilly Foster mine, Putnam County, and at Edwards, N. Y.; in the meteorite from Bishopville, S. C.

Bronzite, $(\text{Mg,Fe})_2(\text{SiO}_3)_2$.

Orthorhombic, bipyramidal class. Same elements of crystallization as for enstatite. Distinct crystals have been observed only in the meteorite from Breitenbach, Bohemia. Prism angle is $91^\circ 44'$. Occurs in compact, crystalline, fibrous, or granular masses.

Distinct prismatic cleavage. Pronounced parting parallel to the macropinacoid producing fibrous or irregular wavy surfaces with a chatoyant bronzy luster. Hardness 5 to 6. Specific gravity 3.2 to 3.5. Translucent to opaque. Silky metallic, bronzy luster. Darker in color than enstatite, usually brown, green, or yellowish. Uncolored streak.

$(\text{Mg,Fe})_2(\text{SiO}_3)_2$. May be interpreted as an isomorphous mixture of MgSiO_3 and FeSiO_3 . FeO varies between 5 and 16%. May contain some Al_2O_3 and Fe_2O_3 . Sometimes considered a ferruginous enstatite. Fuses with great difficulty. Insoluble in acids, except hydrofluoric.

Occurrences the same as for enstatite.

Hypersthene, $(\text{Fe,Mg})_2(\text{SiO}_3)_2$.

Orthorhombic, bipyramidal class. $a : b : c = 1.0295 : 1 : 0.5868$. Occurs rarely in small, well developed, or in large indistinct crystals. Usually in granular and foliated aggregates, or in cleavage masses.

Perfect brachypinacoidal, and indistinct prismatic and macropinacoidal cleavages. Uneven fracture. Brittle. Hardness 5 to 6. Specific gravity 3.3 to 3.5. Translucent to opaque. Color black, brownish black, or green. Pearly to metalloid luster. A copper red iridescence is often to be noted on the macropinacoid, due to the occurrence of microscopic, tabular inclusions. These inclusions may be ilmenite, brookite, goethite, or hematite.

$(\text{Fe,Mg})_2(\text{SiO}_3)_2$. Similar to bronzite in composition, but contains more iron than magnesium; 15 to 34% FeO, 11 to 22% MgO. As much as 10% Al_2O_3 may be present, also varying amounts of Fe_2O_3 , CaO, or MnO. Fuses more readily than bronzite, and forms a black magnetic mass. Slightly acted upon by acids.

Hypersthene occurs in many igneous rocks, such as gabbros, norites, andesites, and peridotites. It is found also in some meteorites. It is commonly associated with a plagioclase feldspar, especially labradorite. Occurs on St. Paul's Island off the coast of Labrador; Laacher See, Rhenish Prussia; Farsund, Norway; Greenland; Isle of Skye, Scotland; Mount Shasta, Cal.; Buffalo Peaks, Colo.; along the Hudson River and in the Adirondack Mountains, N. Y.

On account of the metalloid iridescence or schiller, hypersthene is sometimes used in jewelry.

MONOCLINIC PYROXENES

(a) Non-aluminous varieties.

DIOPSIDE, $\text{CaMg}(\text{SiO}_3)_2$.

Monoclinic, prismatic class. $a : b : c = 1.0913 : 1 : 0.5895$, $\beta = 105^\circ 51'$. Crystals are generally short and thick, and nearly square or octagonal in outline. Striations parallel to the basal pinacoid occur commonly on the faces of the vertical zone. Figures 123a and 123b show the following forms:

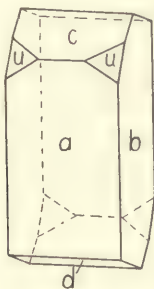


FIG. 123a

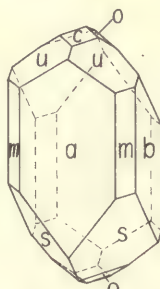


FIG. 123b

the three pinacoids, a , b , and c ; unit prism m ; positive unit hemipyramid o ; negative unit hemipyramid u ; positive modified hemipyramid s , ($m=2$), and the positive unit hemiorthodome d . The ortho- and clinopinacoids are generally larger than the faces of the unit prism. Contact and polysynthetic twins parallel to the basal pinacoid. Partings parallel to these pinacoids are often observed. Occurs also in compact, broad columnar, granular, lamellar, or rarely fibrous masses.

Distinct prismatic cleavage. Brittle. Hardness 5 to 6. Specific gravity 3.2 to 3.3. Uneven to conchoidal fracture. Transparent to opaque. Vitreous, resinous, or dull luster; sometimes inclining to pearly on the partings parallel to the basal pinacoid. Generally light to dark green in color; also colorless, gray, yellow, and rarely blue. Zonal distribution of color is not uncommon. The dark green varieties contain much FeO . White to greenish streak. *Diallage* is a thin, foliated, or lamellar variety, green or brown in color, having a hardness of 4 to 6, and a specific gravity of 3.2 to 3.5. *Diallage* is in part also closely related to *augite*. *Omphacite* is a green variety of *diallage*.

$\text{CaMg}(\text{SiO}_3)_2$. Usually contains as much as 5% of FeO ; in *diallage*, however, as high as 8 to 16%. Small amounts of Al_2O_3 and MnO may also be present; in *diallage* Al_2O_3 varies between 1 and 4%. *Chrome-diopside*

contains from 1 to 3% Cr_2O_3 . More or less fusible to a dark colored or green glass. Not acted upon by common acids. Alters to serpentine, talc, chlorite, and limonite.

Occurs in granite, gabbro, basalt, pyroxenite, peridotite, and leucite lava; also in crystalline schists, limestones, and dolomites. Commonly associated with vesuvianite, scapolite, garnet, amphibole, orthoclase, titanite, apatite, tourmaline, spinel, rutile, and so forth. Found at Mussa Alp, Piedmont; Zermatt, Switzerland; various places in the Tyrol; Pargas, Finland; Nordmark, Sweden; Laveline, Vosges; Leucite Hills, Wyo.

HEDENBERGITE, Calcium-iron Pyroxene, $\text{CaFe}(\text{SiO}_3)_2$.

Monoclinic, prismatic class. $a : b : c = 1.0912 : 1 : 0.5843$, $\beta = 105^\circ 25'$. Crystals are rare; usually as dark, greenish black, compact lamellar masses. Light greenish streak. Specific gravity 3.2 to 3.6, increasing with the percentage of iron. Contains about 30% of FeO and 22% of CaO. Sometimes as much as 6.5% of MnO may be present in *manganhedenbergite* from Vester Silfberg, Lalarne, Sweden. Occurs with magnetite in crystalline limestone at Tunaberg and Nordmark, Sweden; also at Arendal, Norway.

SCHEFFERITE, Manganese Pyroxene, $(\text{Ca}, \text{Mg})(\text{Fe}, \text{Mn})(\text{SiO}_3)_2$.

Monoclinic, prismatic class. Tabular and prismatic crystals, also in crystalline masses. Distinct prismatic cleavage. Yellowish to reddish brown or black in color. Contains from 8 to 10% of MnO, 9 to 15% of MgO. *Iron-schefferite* contains as much as 15% of FeO. Occurs in limestone at Långban, Sweden; in the Caucasus Mountains; containing zinc at Franklin Furnace, N. J.

JEFFERSONITE, Manganese-zinc Pyroxene, $(\text{Ca}, \text{Mn})(\text{Mg}, \text{Fe}, \text{Zn})(\text{SiO}_3)_2$.

Monoclinic, prismatic class. Dark green to brownish black in color. Distinct prismatic and orthopinacoidal cleavages. Submetallic luster, resinous on cleavage surfaces. Translucent to opaque. Occurs as large, coarse crystals with rounded edges, and as compact masses in crystalline limestone at Franklin Furnace, N. J. Contains about 10% of MnO and 4 to 10% of ZnO.

Wollastonite, Tabular Spar, $\text{Ca}_2(\text{SiO}_3)_2$.

Monoclinic, prismatic class. $a : b : c = 1.0531 : 1 : 0.9676$, $\beta = 95^\circ 30'$. Crystals are usually elongated parallel to the b axis and tabular in habit. The orthopinacoid predominates oftener than the basal pinacoid. Rarely prismatic in development. Crystals are highly modified. Prism angle is $92^\circ 40'$. Twins parallel to the orthopinacoid. Usually occurs in cleavable, fibrous, granular, and compact masses. The broad or slender fibres may have a parallel or divergent structure.

Perfect basal and orthopinacoidal cleavages; distinct parallel to the positive unit hemi-orthodome. Hardness 4 to 5. Specific gravity 2.8 to 2.9. Vitreous to silky luster, pearly on cleavage surfaces. Uneven fracture.

Brittle. Transparent to translucent. White streak. Usually white in color, also colorless, grayish, yellowish, reddish, or brownish.

$\text{Ca}_2(\text{SiO}_3)_2$. Generally intermixed with calcite, hence, may effervesce with acids. Fuses on thin edges. Decomposes and gelatinizes with hydrochloric acid.

Wollastonite is a typical contact metamorphic mineral and is generally associated with garnet, diopside, vesuvianite, augite, epidote, and calcite. It is found in granular limestone, granite, basalt, and lava. Some localities are Auerbach, Hessen, Germany; Island of Elba; Cziklova, Hungary; Mount Vesuvius; Island of Santorin; Grenville and elsewhere, Quebec, North Burgess and Bastard, Ontario, Canada; Diana, Lewis County, N. Y.; Attleboro, Bucks County, Pa.

(b) *Aluminous varieties.*

AUGITE.

Monoclinic, prismatic class. $a : b : c = 1.0921 : 1 : 0.5893$, $\beta = 105^\circ 40'$. Short columnar crystals with a prism angle of $92^\circ 54'$. Figures 124 and 125 show combinations of the two pinacoids, a and b ; unit prism m ; negative hemi-orthodome t , ($n=2$); positive unit hemi-pyramid o . The faces of the prism are usually as large or larger than those of the pinacoids. Crystals are generally well developed and in some cases highly modified. Contact twins parallel to the orthopinacoid, figure 126, and penetration twins parallel to the brachy hemipyramid ($n=2$) are common, figure 126a. Occurs also in compact and disseminated grains and granular aggregates, rarely fibrous.

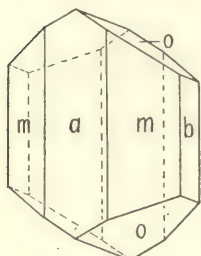


FIG. 124

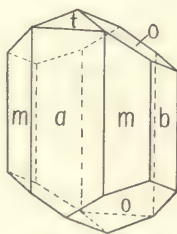


FIG. 125

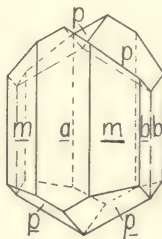


FIG. 126

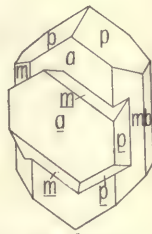


FIG. 126a

Fairly distinct prismatic cleavage. Conchoidal to uneven fracture. Brittle. Hardness 5 to 6. Specific gravity 3.2 to 3.6, varying with the composition. Usually opaque, may be translucent. Commonly black or greenish black in color, also leek green. Grayish green streak.

Four varieties may be distinguished:—

Fassaite. Brownish and green crystals, often resembling diopside and epidote. Typical contact metamorphic mineral. Occurs in the Fassathal Tyrol; Mount Vesuvius; Traversella, Piedmont.

Leucaugite. Contains magnesium, calcium, and aluminium, but little or no iron. Light colored, white or gray. Specific gravity 3.2.

Common augite. Contains considerable iron. Dark green to black in color. As an essential constituent, it occurs disseminated and in well developed crystals in the older basic rocks; in acid rocks it is generally an accessory mineral. When it occurs in basic rocks it is more generally brownish, in acid rocks green. Also found in metamorphic ore deposits, for example, the magnetite deposits of Arendal, Norway; also in crystalline limestone at Pargas, Finland.

Basaltic augite. Characteristic of volcanic rocks, such as andesite, phonolite, basalt, melaphyre, tuff, lava, and volcanic sand and ashes. Crystals are very simple, usually pitch black in color, and at times with rounded surfaces. Conchoidal fracture. Translucent to opaque. In thin section distinctly pleochroic. May contain several percent of TiO_2 or Na_2O . Occurs on the Kaiserstuhl, Baden; Borešlaw, Bohemia; Laacher See, Rhenish Prussia; Mount Vesuvius; Mount Aetna; the Azores and Cape Verde Islands; Fassathal, Tyrol; Thetford, Vt.

Groth interprets augite as being an isomorphous mixture of three molecules: $(\text{Mg,Fe})\text{Ca}(\text{SiO}_3)(\text{SiO}_3)$, $(\text{Mg,Fe})\text{Al}(\text{AlO}_3)(\text{SiO}_3)$, and $(\text{Mg,Fe})\text{Fe}(\text{FeO}_3)(\text{SiO}_3)$. The amount of FeO present is usually about 10%. Sodium is not uncommonly present. Fuses and often forms a magnetic glass. Slightly acted upon by acids. Alters to a fibrous hornblende having the form of augite, which is termed *uralite*, also to serpentine. The end alteration products are limonite, quartz, and calcite.

A common rock mineral, being an essential or accessory constituent of basalt, melaphyre, diabase, tuff, and volcanic sand and ashes. Occurs also in crystalline schists and is commonly the result of contact metamorphism. Found in meteorites and is formed in many furnace slags.

(c) *Varieties containing alkalis.*

Pectolite, $(\text{Ca,Na}_2)_2(\text{SiO}_3)_2$.

Monoclinic, prismatic class. $a : b : c = 1.1140 : 1 : 0.9864$, $\beta = 95^\circ 20'$. Commonly consists of aggregates of divergent fibres or acicular crystals, sometimes of considerable length. The ends of the individual fibres or crystals are often very sharp. Occurs also in compact, radial masses. Well developed crystals are commonly tabular parallel to the orthopinacoid, but rare.

Basal and orthopinacoidal cleavages. Uneven fracture. Brittle. Hardness 4 to 5. Specific gravity 2.7 to 2.8. White streak. Colorless, white, or grayish white. Translucent to opaque. Vitreous pearly luster, on cleavages silky.

$(\text{Ca}, \text{Na}_2)_2(\text{SiO}_3)_2$. Very similar to wollastonite in composition. Contains about 10% of Na_2O . *Manganopectolite* contains about 4% of MnO . Fuses easily to a white glass. Yields water in a closed tube. Decomposed with hydrochloric acid with the separation of silica. Phosphoresces when crushed in the dark.

Occurs in fissures and cavities in basic eruptive and metamorphic rocks. Commonly associated with the zeolites, prehnite, and so forth. Some localities are Monte Baldo, Fassathal, and Monzoni, Tyrol; Ayrshire and Edinburghshire, Scotland; Thunder Bay, Ontario, Canada; Bergen Hill, N. J.; Isle Royale, Mich.; Magnet Cove, Ark.

JADEITE, $\text{NaAl}(\text{SiO}_3)_2$.

Monoclinic, has been considered triclinic, but microscopic examination shows that it is monoclinic with the general properties of the pyroxenes. Never in crystals, always as compact, microcrystalline, granular, foliated, or fibrous aggregates.

Fibres have cleavages at angles of about 93° and 87° . Tough. Splintery fracture. Hardness 6 to 7. Specific gravity 3.3 to 3.5. Subvitreous luster, pearly on cleavages. Translucent. Usually green in color, apple to emerald green, bluish, green, leek green, greenish or yellowish white, white with green spots, or colorless. Uncolored streak.

$\text{NaAl}(\text{SiO}_3)_2$. Fuses easily to a transparent blebby glass. Colors the flame yellow. Insoluble in or only slightly attacked by hydrochloric acid, after fusion readily decomposed. *Chloromelanite* is dark green to almost black in color and contains considerable FeO , CaO , and MgO .

Occurs embedded in crystalline schists and in rounded masses in secondary deposits in Burma, Thibet, and southern China. The European and American localities are uncertain.

Highly prized in China. It is used for the manufacture of ornaments and utensils of various kinds. Often found with relics of prehistoric man. Jadeite is one of the tough, white to greenish minerals included in the general term *jade*, page 252.

Spodumene, Triphane, $\text{LiAl}(\text{SiO}_3)_2$.

Monoclinic, prismatic class. $a : b : c = 1.1238 : 1 : 0.6355$, $\beta = 110^\circ 20'$. Long, columnar crystals, the unit prism predominating; also tabular parallel to the orthopinacoid. Vertical striations and furrows. Prism angle about 93° . Twins parallel to the orthopinacoid. Crystals are often very large. Crystals from the Etta mine, near Keystone, Pennington County, S. Dak., measured 30 feet in length and about $2\frac{1}{2}$ feet in diameter. More commonly in cleavable masses and broad columnar aggregates.

Perfect prismatic cleavage. Very easy parting parallel to the orthopinacoid. Uneven to subconchoidal fracture. Brittle. Transparent to opaque. Vitreous luster, pearly on cleavages. White, greenish and grayish white, yellowish green, apple to emerald green, lilac pink, and purple in color. Hardness 6 to 7. Specific gravity 3.1 to 3.2. *Hiddenite* is a yellow to emerald green variety from Stony Point, Alexander County, N. C. A transparent, lilac pink variety from Pala, San Diego County, Cal., which phosphoresces with an orange pink light when exposed to oscillating electric dis-

charges, the X-rays, ultra-violet light, or to radium emanations, is called *kunzite*.

$\text{LiAl}(\text{SiO}_3)_2$. Usually contains sodium replacing some of the lithium; FeO and CaO may also be present. In hiddenite there is a small percentage of Cr_2O_3 , and in kunzite small amounts of the oxides of zinc, nickel, and manganese. Fuses easily, turns white, intumesces, and colors the flame purple red, indicating lithium. Insoluble in acids. Of its many alteration products mention will be made only of albite, muscovite, eucryptite, cymatolite (a mixture of albite and muscovite), and quartz.

Occurs in pegmatite veins with tourmaline, beryl, garnet, lepidolite, feldspar, mica, and quartz as the principal associates. Some localities are: Island of Uto, Sweden; Killiney, Dublin County, Ireland; Sterzing, Tyrol; Sterling and Goshen, Mass.; Branchville, Conn.; Windham and Peru, Me.; Stony Point, Alexander County, N. C.; Pennington County, S. Dak.; Pala, San Diego County, Cal.

Kunzite and hiddenite are used for gem purposes. The output of the Etta mine, Pennington County, S. Dak., is used as an important source of lithium compounds, especially the carbonate. Lithium salts are used in the manufacture of red fire and for medicinal purposes.

ACMITE, Aegirite, $\text{NaFe}(\text{SiO}_3)_2$.

Monoclinic, prismatic class. $a : b : c = 1.996 : 1 : 0.6012$, $\beta = 106^\circ 49'$. Long prismatic crystals, more or less tabular parallel to the orthopinacoid, with vertical striations or furrows. The terminal faces are very acute on *acmite*, on *aegirite* more obtuse. Prism angle $92^\circ 49'$. Twins parallel to the orthopinacoid are rather common. Also in very slender hair-like crystals and fine fibrous aggregates.

Distinct prismatic and indistinct clinopinacoidal cleavages. Perfect parting parallel to the orthopinacoid. Uneven to subconchoidal fracture. Brittle. Hardness 6 to 6.5. Specific gravity 3.4 to 3.55. Vitreous luster, inclining to resinous. Subtransparent to opaque. Reddish brown, brownish black, greenish, or greenish black in color. Yellowish gray to dark green streak.

$\text{NaFe}(\text{SiO}_3)_2$. Usually contains Al_2O_3 , FeO, MnO, CaO, MgO, and Na_2O ; rarely TiO_2 . The composition of *acmite* and *aegirite* is practically the same. Acmite crystals usually have the more acute terminal faces and are brown in thin section; aegirite green. *Aegirite-augite* is a green, rock-making augite containing some of the aegirite molecule. They fuse rather easily to a magnetic glass, coloring the flame an intense yellow. Slightly acted upon by acids.

Occurs in alkali rocks, such as, soda and nepheline syenite, soda granite, and phonolite. Some localities are: Aeker and Langesundfjords, Norway; Kola peninsula, Russia; Ditró, Hungary; the Azores; Montreal and Beloeil, Canada; Kangerdluarsuk, Greenland; Magnet Cove, Ark.; Custer County, Colo.; Libertyville, N. J.; Black Hills, S. Dak.

TRICLINIC PYROXENES

Rhodonite, $\text{Mn}_2(\text{SiO}_3)_2$.

Triclinic, pinacoidal class. $a : b : c = 1.0728 : 1 : 0.6213$, $\alpha = 103^\circ 18'$, $\beta = 108^\circ 44'$, $\gamma = 81^\circ 39'$. Tabular and prismatic crystals, comparatively large and with rounded edges, but not very common. Usually in fine-grained, cleavable, or compact masses, also in disseminated grains.

Prismatic and basal cleavages. Prism angle $92^\circ 28'$. Compact masses are very tough, crystals brittle. Conchoidal to uneven fracture. Hardness 5 to 6. Specific gravity 3.4 to 3.7. Vitreous luster, pearly on cleavages. Crystals are often transparent, masses translucent to opaque. Rose red in color, masses are yellowish, greenish, or brownish; often black externally, due to the oxidation of MnO on exposure. White streak.

$\text{Mn}_2(\text{SiO}_3)_2$. Calcium and iron often replace some of the manganese. *Bustamite* is a radial fibrous, grayish red variety from Mexico, containing from 9 to 20% of CaO. Compact masses are sometimes mixed with varying amounts of CaCO_3 and SiO_2 . Turns black and fuses easily with slight intumescence to a brownish glass. Slightly acted upon by acids. Varieties containing an admixture of CaCO_3 effervesce with acids. *Hydrorhodonite* is an alteration product containing water.

Occurs with rhodochrosite, calcite, quartz, iron ores, franklinite, and tetrahedrite. Some localities are Elbingerode, Hartz Mountains; Kapnik and Rézbánya, Hungary; St. Marcel, Italy; Långban and Pajsberg, Sweden; Ekaterinburg, Ural Mountains; Peru; Cummington, Mass.; Cumberland, R. I.; Franklin Furnace district, N. J., see *fowlerite*.

Fowlerite, $(\text{Mn,Fe,Ca,Zn,Mg})_2(\text{SiO}_3)_2$.

Occurs in large reddish crystals and compact masses in calcite in the Franklin Furnace district, N. J. It is a variety of rhodonite, containing from 5 to 8% of ZnO, 3 to 9% of FeO, and 6 to 7% of CaO.

BABINGTONITE, $\left\{ \begin{array}{l} (\text{Ca,Fe,Mn})_2(\text{SiO}_3)_2 \\ \text{Fe}_2(\text{SiO}_3)_2 \end{array} \right.$

Triclinic, pinacoidal class. $a : b : c = 1.0691 : 1 : 0.6308$, $\alpha = 104^\circ 21\frac{1}{2}'$, $\beta = 108^\circ 31'$, $\gamma = 83^\circ 34'$. Small six or eight sided, tabular or prismatic crystals, resembling augite somewhat in form. Faces often striated. Occurs also in radial fibrous and fine granular aggregates. Distinct prismatic cleavages with an angle of $92^\circ 37'$. Brittle. Hardness 5 to 6. Specific gravity 3.35 to 3.4. Vitreous luster. Subtransparent to opaque. Greenish to brownish black, or black in color. Greenish gray streak.

An isomorphous mixture in varying proportions of $(\text{Ca,Fe,Mn})(\text{SiO}_3)_2$ and $\text{Fe}_2(\text{SiO}_3)_2$. According to Palache and Fraprie, the molecules are present in the proportion of about $5\frac{3}{4}$ parts of the first to 1 of the second in the babingtonite from Somerville, Mass. Aluminium and titanium may also be present. Fuses easily to a black, magnetic globule. Not acted upon by acids. Alters to limonite.

Commonly associated with prehnite, quartz, epidote, pyrite, garnet, hornblende, chlorite, feldspar, and calcite. Found at Arendal, Norway; Herbornseelbach, Nassau; Baveno, Italy; Somerville and Athol, Mass.

AMPHIBOLE GROUP

This group of minerals is closely related to the pyroxenes and consists of metasilicates of magnesium, aluminium, iron, calcium, sodium, and potassium, corresponding to the general formula $M''_4(\text{SiO}_3)_4$. Like the pyroxenes, these minerals crystallize in the orthorhombic, monoclinic, and triclinic systems. The monoclinic representatives are the most important. The amphiboles are not as fully developed as the pyroxenes, there being fewer members. They are also simpler crystallographically. The prism angles are about 56° and 124° . The prismatic cleavages are more prominent on the amphiboles than on the pyroxenes.

In order to show the striking crystallographic similarity of the pyroxenes and amphiboles, the elements of crystallization of two corresponding representatives of the monoclinic system may be written as follows:—

	a	b	c	β
Diopside (Pyroxene)	1.0522	1	0.2959,	$90^\circ 22'$
Tremolite (Amphibole)	1.0598	1	0.2938,	$90^\circ 34'$

The principal differences between the pyroxene and amphibole groups may be tabulated in a general way, as follows:—

	<i>Pyroxenes</i>	<i>Amphiboles</i>
Crystals,	{ Short prismatic, complex.	Long prismatic, simple.
Prism angles,	{ Pseudo-tetragonal.	Pseudo-hexagonal.
Cleavages,	87° and 93° .	56° and 124° .
Masses,	Prismatic.	Prismatic, more distinct.
Specific gravity,	Lamellar or granular.	Columnar or fibrous.
Chemical composition,	Higher.	
	Alter to amphibole.	Magnesium and the alkalis are more prominent.

I. ORTHORHOMBIC SERIES (Bipyramidal Class)

	a	b	c
ANTHOPHYLLITE, $(\text{Mg,Fe})_4(\text{SiO}_3)_4$.	0.5137	1	?
GEDRITE, $(\text{Mg,Fe})_4(\text{SiO}_3)_2(\text{SiO}_3)_2$ } $(\text{Mg,Fe})_2\text{Al}_2(\text{AlO}_3)_2(\text{SiO}_3)_2$ }	0.5229	1	0.217



2. MONOCLINIC SERIES

(Prismatic Class).

(a) Non-aluminous varieties:—

	<i>a</i>	<i>b</i>	<i>c</i>	β
Tremolite, $\text{CaMg}_3(\text{SiO})_4$.	0.5415	: 1	: 0.2886,	$105^\circ 11\frac{1}{2}'$
Actinolite, $\text{Ca}(\text{Mg,Fe})_3(\text{SiO}_3)_4$.				
RICHTERITE, $(\text{Mg,Ca,Mn,K}_2,\text{Na}_2)_4(\text{SiO}_3)_4$.				
	0.5499	: 1	: 0.2854,	$104^\circ 14'$

(b) Aluminous varieties:—

HORNBLLENDE,

$\text{Ca}(\text{Mg,Fe})_3(\text{SiO}_3)_2(\text{SiO}_3)_2$.	0.5318	: 1	: 0.2936,	$104^\circ 58'$
$\text{Al}_2(\text{Mg,Fe})_2(\text{AlO}_3)_2(\text{SiO}_3)_2$.				
$\text{Fe}_2(\text{Mg,Fe})_2(\text{FeO}_3)_2(\text{SiO}_3)_2$.				

(c) Varieties containing alkalis:—

ARFVEDSONITE,

$(\text{Fe,Mg,Na}_2,\text{Ca})_4(\text{SiO}_3)_2(\text{SiO}_3)_2$.	0.5496	: 1	: 0.2975,	$104^\circ 15\frac{1}{2}'$
$(\text{Ca,Mg,Fe})_2(\text{Al,Fe})_2(\text{AlO}_3)_2(\text{SiO}_3)_2$.				

GLAUCOPHANE,

$\text{Al}_2\text{Na}_2(\text{SiO}_3)_4$.	0.53	: 1	: 0.29,	105°
$(\text{Mg,Fe,Ca})_4(\text{SiO}_3)_4$.				

RIEBECKITE,

$\text{Fe}_2\text{Na}_2(\text{SiO}_3)_4$.	0.5475	: 1	: 0.2295,	$103^\circ 50'$
$\text{Fe}_4(\text{SiO}_3)_4$.				

3. TRICLINIC SERIES

(Pinacoidal Class).

AENIGMATITE,

$(\text{Na}_2,\text{K}_2,\text{Fe})_4[(\text{Si,Ti})\text{O}_3]_4$.	<i>a</i>	<i>b</i>	<i>c</i>
$\text{Al}_2\text{Na}_2(\text{SiO}_3)_4$.	0.6627	: 1	: 0.3505
$(\text{Fe,Mn,Mg})_3\text{Ca}(\text{SiO}_3)_4$.			
	$\alpha = 90^\circ 6'$	$\beta = 102^\circ 13'$	$\gamma = 89^\circ 54'$

The amphiboles and pyroxenes are important rock minerals. According to Clarke, about 17% of the igneous rocks consist of the minerals of these groups.

ORTHORHOMBIC AMPHIBOLES

ANTHOPHYLLITE, $(\text{Mg,Fe})_4(\text{SiO}_3)_4$.

Orthorhombic, bipyramidal class. $a : b : c = 0.5137 : 1 : ?$. Crystals are rare, never with terminal planes. Generally in lamellar or fibrous masses or aggregates; also asbestiform. Perfect prismatic cleavage, angle $54^\circ 33'$; distinct macro- and brachypinacoidal cleavages. Hardness 5 to 6. Specific gravity 3.1 to 3.2. Vitreous luster, pearly on cleavages; metallic schiller on the brachypinacoid. Translucent to subtransparent.

$(\text{Mg,Fe})_4(\text{SiO}_3)_4$. May contain some Al_2O_3 . Fuses with difficulty. Not acted upon by acids. Alters to talc.

Usually found in crystalline schists, especially those containing hornblende. Occurs at Kongsberg, Modum, and elsewhere in Norway; Stansvik, Finland; Hermannschlag, Moravia; Jenks corundum mine, Franklin, Macon County, N. C.; Rockport, Mass. Anthophyllite is not common mineral.

GEDRITE is similar to anthophyllite in its general physical properties, but contains more Al_2O_3 . For formula, see page 250. Occurs at Gèdres, France; Bamle and elsewhere, Norway; Fiskernaes, Greenland.

These minerals correspond in a general way to enstatite, bronzite, and hypersthene of the pyroxene group.

MONOCLINIC AMPHIBOLES

(a) Non-aluminous varieties.

Tremolite, $\text{CaMg}_3(\text{SiO}_3)_4$.

Monoclinic, prismatic class. $a : b : c = 0.5415 : 1 : 0.2886$, $\beta = 105^\circ 11\frac{1}{2}'$. Long or short bladed crystals, generally without distinct terminal faces; also as fibrous and asbestiform aggregates, and in compact granular masses.

Perfect prismatic cleavage, angle $124^\circ 11'$. Very brittle. Hardness 5 to 6. Specific gravity 2.9 to 3.1. White to gray or yellow in color. Transparent to opaque. Vitreous to silky luster.

$\text{CaMg}_3(\text{SiO}_3)_4$. Contains little or no FeO , not over 3%. *Hexagonite* is an amethystine to lavender variety from Edwards, St. Lawrence County, N. Y., containing about 2% of MnO with small amounts of sodium and fluorine. Fuses with difficulty. Not acted upon by acids. Alters to talc.

Tremolite is a contact metamorphic mineral, occurring in granular limestones and dolomites, and talc schists. Found at Campolongo, St. Gothard district, Switzerland; various places in Sweden and Hungary; Lee, Mass.; Canaan, Conn.; Bryam, N. J.; Easton, Pa.; Edenville, Orange County, and Gouverneur and Edwards, St. Lawrence County, N. Y.; Litchfield, Pontiac County, Quebec, and Renfrew and Lanark counties, Ontario, Canada.

Actinolite, $\text{Ca}(\text{Mg,Fe})_3(\text{SiO}_3)_4$.

Monoclinic, prismatic class. $a : b : c = 0.5415 : 1 : 0.2886$, $\beta = 105^\circ 11\frac{1}{2}'$. Long or short bladed crystals, generally without terminal faces; more usually as divergent or irregular, columnar, fibrous, or asbestiform aggregates; also in granular masses. *Nephrite* is a compact variety of tremolite or actinolite, and is included in the general term *jade*, see page 247.

Perfect prismatic cleavage. Basal parting. Vitreous luster. Hardness 5.5 to 6. Specific gravity 2.9 to 3.2. Usually green in color, also white, gray, or colorless. The green color is due to the presence of ferrous iron. Strongly pleochroic.

$\text{Ca}(\text{Mg,Fe})_3(\text{SiO}_3)_4$. Often considered an isomorphous mixture of $\text{CaMg}_3(\text{SiO}_3)_4$ and $\text{CaFe}_3(\text{SiO}_3)_4$. Contains from 6 to 13% of FeO , also

small amounts of Al_2O_3 and Na_2O . Fuses to a gray enamel. But slightly acted upon by acids. Alters to talc, chlorite, epidote, or to an aggregate of serpentine and calcite.

Actinolite occurs in crystalline schists; sometimes in such quantities that the rock may be termed *actinolite schist*. Often formed by contact metamorphism. Some localities are Greiner, Zillerthal, Tyrol; Arendal, Norway; Zöblitz, Saxony; Bolton, Brome County, Quebec, Canada; Willis's Mountain, Buckingham County, Va.; Bare Hills, Md.; Franklin Furnace, N. J.; Providence, Delaware County, and Kennett, Chester County, Pa.; Lee and elsewhere, Mass.; Windham and elsewhere, Vt.

Asbestos.

Under this term are included fibrous varieties of tremolite, actinolite, and other non-aluminous amphiboles. The fibres are sometimes long, parallel, flexible, and easily separated by the fingers. The very fine fibrous and more or less silky varieties are called *amianthus*; those which are stiff or felt-like, *byssolite*. *Mountain leather*, *mountain cork*, and *mountain wood* are compact, irregularly matted, and only slightly flexible varieties.

Amphibole asbestos is generally termed *long fibered asbestos*, while the serpentine asbestos, see page 226, is called *short fibered*. The heat resisting property of the amphibole asbestos is about the same as that of the chrysotile asbestos, but the non-conductivity of heat and strength of fibre is less. Chrysotile asbestos gives more satisfactory results. The only producing locality in the United States for amphibole asbestos is Sall Mountain, Georgia. Before the increased output of the better chrysotile asbestos by the Canadian mines, there were a number of small mines of the amphibole variety in Massachusetts, Connecticut, Virginia, North Carolina, South Carolina, and Georgia.

For the uses of asbestos, see page 227.

RICHTERITE, $(\text{Mg}, \text{Ca}, \text{Mn}, \text{K}_2, \text{Na}_2)_4(\text{SiO}_3)_4$. Monoclinic. Occurs in elongated crystals, usually without distinct terminations. Yellow, red, or brown in color. Specific gravity 2.8 to 3.1. Transparent to translucent. Contains up to 9% of the alkalis. Found in the manganese deposits of Långban and Pajsberg, Sweden. *Cummingstonite* resembles anthophyllite in composition but is monoclinic. Occurs at Cummington, Mass.; Kongsberg, Norway; Greenland. *Grünerite* is an iron amphibole with the formula $\text{Fe}_4(\text{SiO}_3)_4$, occurring usually in fibrous or lamellar masses with a brown color and silky luster. Contains but small amounts of MgO and Al_2O_3 . Specific gravity 3.7. Found at Colobrières, France, and in the Lake Superior iron district.

(b) Aluminous varieties.

HORNBLENDE.

Monoclinic, prismatic class. $a : b : c = 0.5318 : 1 : 0.2936$, $\beta = 104^\circ 58'$. Short, prismatic crystals with a pseudo-hexagonal development, being six-sided and frequently terminated by faces which simulate a rhombohedron. Prism angle is $55^\circ 49'$, but varies with the composition. Crystals are usually very simple, consisting of combinations of the unit prism m , pos-

itive unit hemipyramid *o*, basal pinacoid *c*, clinopinacoid *b*, orthopinacoid *a*, unit clinodome *d*, and the clinoprism *e* ($n=3$), see figures 127, 128, 129 and 130. Twinning parallel to the orthopinacoid, figure 131. Parallel grouping with augite and diallage is sometimes observed. Occurs also in coarse or fine, columnar, bladed, or fibrous aggregates; further in lamellar or granular masses.

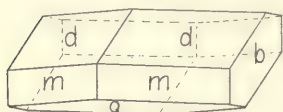


FIG. 127

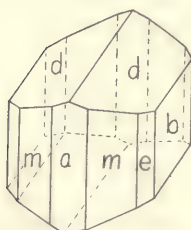


FIG. 128

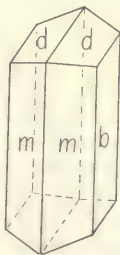


FIG. 129

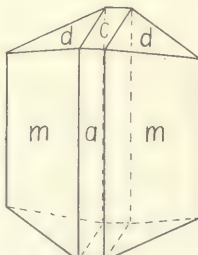


FIG. 130

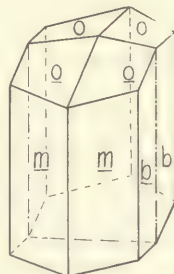


FIG. 131

Perfect prismatic cleavage. Hardness 5 to 6. Specific gravity 2.9 to 3.3. Vitreous to silky luster. Usually dark in color, green, brown, to black; more rarely bluish or dark blue. Grayish green to grayish brown streak. Strongly pleochroic. May be transparent, but generally only translucent to opaque.

The more important varieties of hornblende are:—

(1) *Common hornblende*. Generally black, dark green, or leek green in color. Simple crystals. More usually in compact, cleavable grains and masses, or fibrous aggregates. Contains considerable FeO.

(2) *Basaltic hornblende*. Brownish black to pitch black in color. Contains much iron, TiO_2 , Na_2O , and K_2O . Occurs in disseminated crystals and irregular grains in basic igneous rocks.

(3) *Edenite*. Light colored, white, gray, or pale green. Contains but little iron. Occurs in crystalline limestone at Edenville, N. Y.

(4) *Pargasite*. This variety is rather closely related to edenite. Light bluish green to grayish black, more or less rounded crystals. Occurs as a contact metamorphic mineral in gneisses and crystalline limestone. Found at Pargas, Finland; Grenville, Quebec, Canada; Phippsburg, Me.

In chemical composition hornblende is similar to augite of the pyroxene group, see page 245. It may be considered as an isomorphous mixture of



$\text{Ca}(\text{MgFe})_3(\text{SiO}_3)_2(\text{SiO}_3)_2$, $\text{Al}_2(\text{Mg,Fe})_2(\text{AlO}_3)_2(\text{SiO}_3)_2$, and $\text{Fe}_2(\text{Mg,Fe})_2(\text{FeO}_3)_2(\text{SiO}_3)_2$. There may be as much as 23% of FeO, 7% of Fe_2O_3 , 18% of Al_2O_3 , 14% of MgO, and 12% of CaO present, also small amounts of Na_2O and K_2O , and up to 7% of TiO_2 . A very small per cent of H_2O is usually present, which tends to distinguish hornblende from augite. Fuses to a dark colored magnetic glass, the ease of fusibility increases with the percentage of iron and the alkalis. Acted upon by acids after fusion. Alters to chlorite, epidote, calcite, siderite, biotite, limonite, and quartz. *Uralite* is pyroxene altered to amphibole, with the form of the original mineral but the cleavage of amphibole. Pyroxenes commonly alter in this way and the process is termed *uralitization*.

Hornblende is an essential or accessory constituent of many plutonic igneous rocks, especially granite, syenite, and diorite; also of hornblende schist, andesite, phonolite, basalt, and crystalline limestone. There are many localities, but only a few will be given:—Arendal and Kongsberg, Norway; various places in Sweden and Finland; Mount Vesuvius; Aussig and Teplitz, Bohemia; Thomaston, Me.; Russell, Pierrepont, and DeKalb, St. Lawrence County, N. Y.; Silver Cliff, Colo.

(c) *Varieties containing alkalis.*

ARFVEDSONITE.

Monoclinic, prismatic class. $a : b : c = 0.5496 : 1 : 0.2975$, $\beta = 104^\circ 15\frac{1}{2}'$. Crystals may be large and prismatic, or small and tabular; not common. Usually in columnar aggregates, or in grains. Twins parallel to the orthopinacoid. Very perfect prismatic cleavage with an angle of $56^\circ 5'$. Uneven fracture. Brittle. Hardness 5.5 to 6. Specific gravity 3.45. Vitreous luster. Dark bluish black to black in color. Dark bluish gray streak, which distinguishes it from aegirite having a yellowish gray to greenish gray streak. Opaque, transparent in thin sections.

Chemically it may be considered as an isomorphous mixture of $(\text{Fe,Mg,Na}_2\text{Ca})_4(\text{SiO}_3)_4$ and $(\text{Ca,Mg,Fe})_2(\text{Al,Fe})_2(\text{AlO}_3)_2(\text{SiO}_3)_2$. Fuses easily with intumescence and yields a black magnetic globule, coloring the flame yellow. Not acted upon by acids. *Barkevikite* is intermediate between arfvedsonite and basaltic hornblende.

Occurs in igneous rocks containing much sodium, especially in nepheline syenites and phonolites. Found at Kangerdluarsuk, Greenland; Aker, Langesundfiord, and Klein-Arö, Norway; Kola peninsula, Russia.

KATOFORITE is an amphibole containing considerable sodium and iron and is closely related to hornblende. Occurs in syenite at Langesundfiord, Norway.

GLAUCOPHANE.

Monoclinic, prismatic class. $a : b : c = 0.53 : 1 : 0.29$, $\beta = 105^\circ$, approximately. Indistinctly terminated columnar crystals, but usually in broad columnar, fibrous, or granular aggregates and masses.

Perfect prismatic cleavage. Uneven to conchoidal fracture. Brittle. Hardness 6 to 6.5. Specific gravity 3 to 3.15. Vitreous luster, inclining to pearly. Translucent to opaque. Blue, lavender, blue, bluish gray, or bluish black in color. Grayish blue streak. Strongly pleochroic.

May be considered an isomorphous mixture in varying proportions of $\text{Na}_2\text{Al}_2(\text{SiO}_3)_4$ and $(\text{Mg,Fe,Ca})_4(\text{SiO}_3)_4$. Fuses easily.

Occurs in metamorphic rocks only, such as mica schist, eclogite, and crystalline limestone. Found on the islands of Syra and Thermia; Zermatt, Switzerland; St. Marcel, Piedmont; islands of Corsia and Groix; New Caledonia; Quincy, Mass.; Coast Range, Cal.

RIEBECKITE.

Monoclinic, prismatic class. $a : b : c = 0.5475 : 1 : 0.2295$, $\beta = 103^\circ 50'$. Crystals are long columnar without end faces, the only observed forms being the prism and brachypinacoid. Longitudinally striated. The prism angle is about 56° . Occurs also in parallel or divergent fibrous or columnar aggregates.

Perfect prismatic cleavage. Vitreous luster. Specific gravity 3.3. Hardness 4. Black in reflected light, deep blue or green in transmitted.

Chemically, riebeckite is an isomorphous mixture of $\text{Fe}_2\text{Na}_2(\text{SiO}_3)_4$ and $\text{Fe}(\text{SiO}_3)_4$. Fuses easily, coloring the flame an intense yellow. *Crocidolite* is a fibrous variety of riebeckite from Griqualand-West, South Africa, containing more iron and possessing a silky luster or chatoyancy. *Tiger's eye* contains limonite and infiltrated quartz, giving it a yellow brown color. Crocidolite and tiger's eye are secondary formations of riebeckite.

Riebeckite occurs in alkali granites and syenites. Found on the island of Corsica; island of Socotra, in the Indian Ocean; Myndd Mawr, Carnarvonshire, Wales; Roumania; Narsarsuk, Greenland; El Paso County, Colo.; Lake Superior district.

Crocidolite and tiger's eye are used for ornamental purposes and in cheap jewelry.

TRICLINIC AMPHIBOLES

AENIGMATITE.

Triclinic, pinacoidal class. $a : b : c = 0.6627 : 1 : 0.3505$, $\alpha = 90^\circ 6'$, $\beta = 102^\circ 13'$, $\gamma = 89^\circ 54'$. Crystals may be large but indistinct, resembling common hornblende. Twins parallel to the brachypinacoid.

Distinct prismatic cleavages. Uneven fracture. Brittle. Hardness 5 to 5.5. Specific gravity 3.7 to 3.8. Vitreous luster. Translucent to opaque. Black to brownish black in color. Reddish brown streak.

Groth considers aenigmatite as consisting of a mixture of the three molecules: $(\text{Na}_2, \text{K}_2, \text{Fe})_4[(\text{Si}, \text{Ti})\text{O}_3]_4$, $\text{Al}_2\text{Na}_2(\text{SiO}_3)_4$, and $(\text{Fe}, \text{Mn}, \text{Mg})_3\text{Ca}(\text{SiO}_3)_4$. Contains about $7\frac{1}{2}\%$ of TiO_2 . Easily fusible to a brownish black glass. Partially decomposed by acids. *Cossyrile* is a variety occurring in small black crystals on the island of Pantellaria, and contains perhaps little or no TiO_2 .

Found in nepheline syenites at Tunugdliarfik and Kangerdluarsuk, southern Greenland; Kola peninsula, Russia.

LEUCITE, Amphigène, $K_2Al_2Si_4O_{12}$.

Dimorphous, orthorhombic and cubic. At ordinary temperatures crystals are pseudocubic, in that they show what is apparently a tetragonal tris-octahedron, and at times also the cube and rhombic dodecahedron. Their interfacial angles, however, differ slightly from those required in the cubic system. Optically, the crystals are shown to consist of a system of orthorhombic twin lamellae, which can sometimes be recognized by the striations on the faces. Heated to a temperature of about 500° and over, the lamellae disappear and the crystals become isotropic and truly cubic. Thus, it is evident that leucite was formed at a temperature of about 500° and crystallized in the cubic system, but on cooling it became doubly refractive and orthorhombic, the external form being pseudocubic. Generally found in well developed, disseminated crystals, more rarely massive in granular aggregates.

Very imperfect cleavage parallel to what appears to be the rhombic dodecahedron. Conchoidal fracture. Brittle. Hardness 5.5 to 6. Specific gravity 2.45 to 2.5. Vitreous luster, inclining to greasy on fracture surfaces. Translucent, very rarely transparent. White, gray, yellowish, or reddish in color. White streak.

$K_2Al_2Si_4O_{12}$. Groth assumes that leucite is composed of a mixture of salts of the trisilicate and orthosilicic acids, because orthoclase and nephelinite are alteration products. Some potassium is usually replaced by sodium. Infusible. Turns blue when treated with cobalt nitrate solution. Often contains inclusions which are sometimes arranged in some regular manner. Alters to anacite, or to a mixture of feldspar and nephelinite or muscovite, and finally to kaolin. *Pseudoleucite* is a pseudomorphous mixture of feldspar and nephelite from Magnet Cove, Ark.

Leucite occurs only in igneous rocks, especially young eruptives. Also in leucities, leucite basalts, tephrites, and phonolites. Found in the lavas and ejected masses of Mount Vesuvius; Laacher See, Rhenish Prussia; Kaiserstuhl, Baden; Wiesenthal, Saxony; Brazil; Leucite Hills and elsewhere, Wyo.

BERYL, $Be_3Al_2Si_6O_{18}$.

Hexagonal, dihexagonal bipyramidal class. $a : c = 1 : 0.4989$. Crystals are usually long prismatic and very simple, consisting of the prism of the first order and the basal pinacoid. Rarely tabular. Sometimes highly modified. Figure 132 shows a combination of the prism of the first order m , unit and modified ($m=2$) bipyramids of the first order p and u , modified bipyramid of the second order s ($m=2$), dihexagonal bipyramid v ($n=3/2$, $m=2$), and the basal pinacoid c . About fifty forms have been

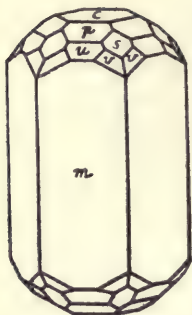


FIG. 132

noted. Crystals are striated vertically and the edges more or less rounded. Occurs also in columnar or granular aggregates, and in rounded grains and masses in secondary deposits.

Distinct basal cleavage. Conchoidal to uneven fracture. Brittle. Hardness 7.5 to 8; is sometimes substituted for topaz in the Mohs scale of hardness. Specific gravity 2.6 to 2.8. Vitreous luster, inclining to pearly on the basal pinacoid. Transparent to translucent. Streak white. Various shades of green, blue, yellow, and reddish in color.

There are three important varieties of beryl:—

(1) *Emerald*. Emerald green in color. Transparent. Highly prized as a precious stone. The color is probably due to a small amount of Cr_2O_3 .

(2) *Aquamarine*. Usually blue to sea green in color, more rarely yellow, yellowish green, rose red, and even colorless (*goshenite*) and water white. Transparent. Also used as a gem, but is not as valuable as the emerald.

(3) *Common beryl*. Generally green or yellowish to grayish white. Crystals are sometimes extremely large, being measured in feet and weighing as much as 1,500 kilograms (Grafton, N. H.). Sometimes also massive. Cloudy and translucent.

$\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$. Al_2O_3 may be partially replaced by Fe_2O_3 or Cr_2O_3 . The oxides of calcium, bivalent iron, potassium, sodium, and caesium may be present in amounts up to about 5%. There is also at times a small percentage of water. Fuses with great difficulty, becoming white and cloudy. Insoluble in acids. Alters to mica or kaolin, the removed beryllium going to form such secondary minerals as bertrandite, hercynite, or beryllonite.

Commonly found in pegmatite veins, gneiss, mica schist, clay slate, or in secondary deposits. The common associates are mica, feldspar, quartz, chrysoberyl, apatite, phenacite, cassiterite, garnet, zircon, and corundum.

Emeralds of a good quality occur near Musa, Colombia; Tokovoja and Mursinka, district of Ekaterinburg, Ural Mountains; Habachthal, Tyrol; Kosseir on the Red Sea, Egypt; Alexander County, N. C.; Mount Antero, Chaffee County, Colo. Aquamarine and other gem beryls are found on the Island of Elba; Mourne Mountains, Ireland; Mursinka and Schaitanka, Ural Mountains; Goshen, Mass.; in secondary deposits in Brazil, India, and elsewhere. Common beryl occurs at Bodenmais, Bavaria; Limoges, France; Cornwall, Eng.; Ehrenfriedersdorf, Saxony; Schaggenwald, Bohemia; very large crystals at Grafton and Acworth, N. H., and at Royalston, Mass.; Paris, Stoneham, elsewhere, Me.; Haddam and Litchfield, Conn.; Chester and Delaware counties, Pa.; Black Hills, S. Dak.

Used for gem purposes and as a source of beryllium and its compounds.



FELDSPAR GROUP

The feldspars constitute the most abundant group of minerals. They are very important rock minerals and, according to the estimates of Clarke,

MONOCLINIC GROUP—ORTHOCLASES
(Prismatic Class)

	a	b	c	β
ORTHOCLASE, KAlSi_3O_8 .				
SODA-ORTHOCLASE, $(\text{Na},\text{K})\text{AlSi}_3\text{O}_8$.	0.6585	1	0.5554,	$116^\circ 3'$
HYALOPHANE, $\left\{ \begin{array}{l} \text{KAlSi}_3\text{O}_8 \\ \text{BaAl}_2\text{Si}_2\text{O}_8 \end{array} \right\}$	0.6356	1	0.5485,	$116^\circ 17'$
	0.6584	1	0.5512,	$115^\circ 35'$

TRICLINIC GROUP—PLAGIOCLASES
(Pinacoidal Class)

	a	β	γ
MICROCLINE, KAlSi_3O_8 .	0.65	116°	90°
ANORTHOCASE, $(\text{Na},\text{K})\text{AlSi}_3\text{O}_8$,	0.6466	$116^\circ 18'$	90°
ALBITE, $\text{NaAlSi}_3\text{O}_8$, (Ab).	0.6330	$116^\circ 27\frac{1}{2}'$	$88^\circ 7'$
Oligoclase, Ab Ab ₃ An.	0.6322	$116^\circ 23'$	$90^\circ 4'$
ANDESINE, Ab ₃ An AbAn.	0.6355	$116^\circ 28'$	$89^\circ 59'$
Labradorite, AbAn AbAn ₃ .	0.6377	$116^\circ 3'$	$89^\circ 54\frac{1}{2}'$
BYTOWNITE, AbAn ₃ An.	Practically the same as for anorthite.		
ANORTHITE, $\text{CaAl}_2\text{Si}_2\text{O}_8$, (An).	0.6347	$115^\circ 55'$	$88^\circ 48'$
CELSIAN, $\text{BaAl}_2\text{Si}_2\text{O}_8$.	?	?	?

make up about 60% of the igneous rocks. Their chemical composition is very similar and may be expressed in general by the formulas $M'AlSi_3O_8$ or $M''Al_2Si_2O_8$, in which the metal may be potassium, sodium, calcium, or more rarely barium. Isomorphous mixtures of the fundamental compounds containing essentially but one of these metals are very common.

Although the feldspars crystallize in the monoclinic and triclinic systems, many of their physical properties are very similar. The prism angles are about 120° . Hardness 6 to 6.5. Specific gravity 2.55 to 2.75. The color varies from white, gray, or colorless to the lighter shades of red, yellow, or green; more rarely dark colored.

All feldspars possess good cleavages in two directions. These cleavages make an angle of 90° on monoclinic feldspars, which are, therefore, called *orthoclases*. In the case of the triclinic feldspars the cleavage angle differs slightly from 90° , and these are generally termed the *plagioclases*. The term plagioclase is, however, often restricted by petrographers to the members of the albite-anorthite series of the triclinic group.

Most classifications of the igneous rocks are based upon the kind of feldspar they contain.

MONOCLINIC FELDSPARS

ORTHOCLASE, Potash Feldspar, Felspar, $KAlSi_3O_8$.

Monoclinic, prismatic class. $a : b : c = 0.6585 : 1 : 0.5554$, $\beta = 116^\circ 3'$. Commonly in well developed crystals, sometimes measuring a foot or more in length. Figures 133 and 134 show some of the common forms:—basal and clinopinacoids c and b , unit prism m , unit and modified positive hemi-orthodomes x and y ($m=2$), unit hemipyramid o , and the clinodome n ($m=2$). Crystals are often highly modified, a total of about 80 forms having been observed. The habit may be prismatic parallel to the c axis, tabular parallel to the clinopinacoid b , or as square columns elongated parallel to the a axis, the basal and clinopinacoids being developed about equally.

There are three very important twinning laws, the first and second being comparatively common.

(1) *Karlsbad law*. The orthopinacoid a acts as the twinning plane, the crystallographic c axis is the twinning axis. Irregular penetration twins are common. Figure 135 shows a twin crystal according to this law. It is designated as a *right* twin, because the basal pinacoid c lies to the right of the hemiorthodome y . The reverse relationship exists in *left* twins. Contact twins are more rarely observed.

(2) *Baveno Law*. The twinning plane is the clinodome n ($m=2$).

Nearly square, columnar, contact twins, Figure 136. Trillings and fourlings according to this law are also noted.

(3) *Manebach Law*. The basal pinacoid c acts as the twinning and composition plane. Contact twins, Figure 137. This law is not as common as the first two.

Other very rare laws involve twinning planes parallel to either the unit prism, a clinoprism with m equal to 3, the unit positive hemipyramid, or to the positive hemi-orthodome y ($m=2$). Occasionally double twinning may be observed, in that crystals according to the Karlsbad law may be further twinned according to the Baveno law.

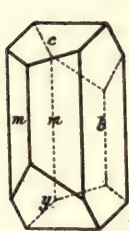


FIG. 133

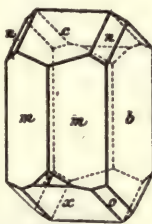


FIG. 134

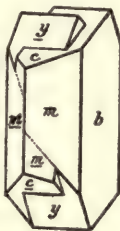


FIG. 135

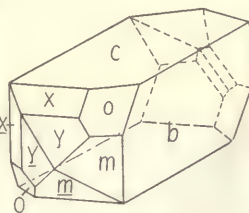


FIG. 136

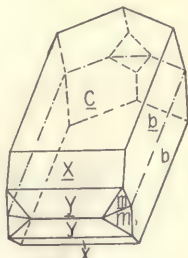


FIG. 137

Aside from occurring in crystals, orthoclase is also found in cleavable masses; further in compact and granular masses, and in irregular grains. Sometimes in masses resembling jasper or flint.

Perfect basal and slightly inferior clinopinacoidal cleavages, making an angle of 90° ; rarely indistinct prismatic cleavage. Parting sometimes distinct parallel to the orthopinacoid. Pearly luster and iridescence on the basal pinacoid, otherwise vitreous luster. Brittle. Conchoidal, uneven to splintery fracture. Hardness 6. Specific gravity 2.5 to 2.58. Transparent and colorless, or opaque and cloudy, and colored. White, gray, yellowish, reddish, brownish, and rarely greenish in color. White streak.

The following varieties may be differentiated:—

(1) *Adularia*. Usually in white to colorless crystals. Transparent or slightly cloudy. Often possesses an excellent opalescence, and is termed *moonstone* and used for gem purposes. Crystals may be simple, single individuals or complex twins, trillings, or fourlings according to the Baveno law. Usually found in cracks and veins in gneiss and mica schist.

(2) *Sanidine*. Occurs in glassy, transparent or translucent crystals. Sometimes termed *glassy feldspar*. Generally colorless, white, or gray. Tabular and square habits, and Karlsbad twins are most common. May contain considerable sodium. Characteristic of such eruptive rocks as rhyolites, trachytes, and phonolites. *Rhyacolite* is a variety occurring in the ejectamenta of Mount Vesuvius and elsewhere.

(3) *Ordinary orthoclase*. Well developed crystals, both as single individuals and twins according to the Karlsbad, Baveno, and other laws; also in cleavable masses. Generally more or less dull colored, yellowish, bluish, flesh red, dark red, or greenish. Translucent to opaque. Common in granites, syenites, gneisses, and pegmatites. *Loxoclase* contains 7 to 9% of Na_2O and 2 to 3% of K_2O , and resembles adularia. *Graphic granites* are intergrowths of orthoclase, or other feldspars, and quartz resembling cuneiform inscriptions, see Figure 138.

(4) *Felsite*. White, brown, or reddish, jasper- or flint-like, cryptocrystalline masses of orthoclase containing quartz.

(5) *Perthite*. Orthoclase interlaminated with albite, although the term is also used for intergrowths of other feldspars. *Perthitic* and *microperthitic structures* refer to the character of such intergrowths. Figure 138a shows a perthitic interlamination of microcline and albite.

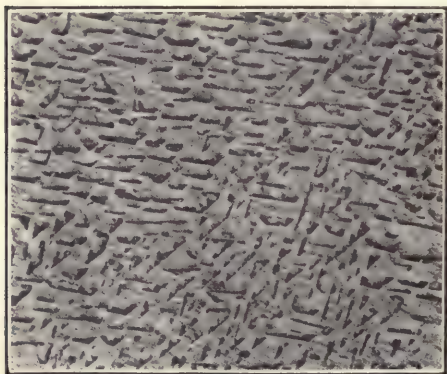


FIG. 138 (Bastin).

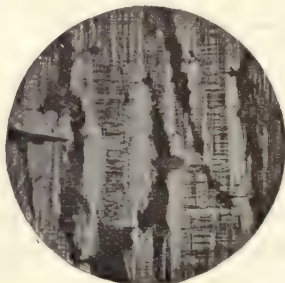


FIG. 138a (Bastin).

KAlSi_3O_8 . Generally contains from 1 to 6% of Na_2O , also smaller amounts of CaO , MgO , BaO , and Fe_2O_3 . Fuses with difficulty, coloring the flame violet. Only slightly acted upon by acids. Alters easily by the action of water alone, more rapidly when water contains carbon dioxide or acids. These tend to remove the alkalies and a portion of the SiO_2 , yielding kaolinite and quartz as the end alteration products. Alters also to muscovite, epidote, zoisite, tourmaline, topaz, alunite, or cassiterite, some of which occur pseudomorphous after orthoclase. At times orthoclase is observed pseudomorphous after analcite, laumontite, prehnite, or leucite.

Orthoclase is especially characteristic of acid plutonic rocks, but occurs also in some eruptive and metamorphic rocks, thus, in granites, syenites, trachytes, phonolites, porphyries, and gneisses. May be of aqueous origin when it occurs as a gangue mineral in metalliferous fissure veins. Some of

the common associates are muscovite, biotite, quartz, tourmaline, the other feldspars, hornblende, apatite, titanite, zircon, beryl, and so forth. Occurs very widely distributed and is often considered the most abundant silicate. A few of the more important localities for crystallized orthoclase are:—St. Gotthard district, Switzerland; Mount Vesuvius; Baveno, Piedmont; Laacher See and Drachenfels, Rhenish Prussia; Karlsbad, Bohemia; Striegau, Silesia; Manebach, Thuringia; Arendal, Norway; Mourne Mountains, Ireland; Cornwall, England; Island of Ceylon; Perth, Quebec, and Bedford, Ontario, Canada. In the United States at Paris, Me.; Acworth, Me.; Haddam and elsewhere, Conn.; Rossie and Hammond, St. Lawrence County, and elsewhere, N. Y.; Mount Antero, Chaffee County, Kokoma, Summit County, and elsewhere in Colorado; etc., etc.

The feldspar of commerce is principally orthoclase or microcline, or an intergrowth of both. It is used chiefly as a constituent of the glaze of porcelain, china, or enamel wares, and as a flux in the manufacture of emery and carborundum wheels. Small quantities are also used in opalescent glasses, artificial teeth, scouring soaps, window washes, fillers for paints, poultry grit, and so forth.* The principal producing localities are Georgetown and Brunswick, Me.; Glastonbury, Chatham, Haddam, and elsewhere, Conn.; Bedford, Batcherville, Crown Point, and Ticonderoga, N. Y.; also various places in Pennsylvania, Maryland, Virginia, Minnesota, and Massachusetts. The production in the United States for 1908 was 70,474 tons, valued at \$428,553. A considerable amount of feldspar is mined annually at Bedford, Ontario, Canada.

SODA-ORTHOCLASE, $(\text{Na},\text{K})\text{AlSi}_3\text{O}_8$.

Includes monoclinic feldspars containing considerable Na_2O , sometimes more than K_2O , but not showing interlamination with albite.

HYALOPHANE, Barium Feldspar, $\text{KAlSi}_3\text{O}_8 + \text{BaAl}_2\text{Si}_2\text{O}_8$.

Monoclinic, prismatic class. $a : b : c = 0.6584 : 1 : 0.5512$, $\beta = 115^\circ 35'$. Colorless, yellowish, or reddish crystals, often resembling adularia. Hardness 6 to 6.5. Specific gravity 2.8. Vitreous luster. Transparent or translucent, cloudy. Conchoidal fracture. Contains from 9 to 20% of BaO and 7 to 9% of K_2O . Some sodium is usually present. Sometimes considered an isomorphous mixture of orthoclase and celadonite. Occurs in the Binnenthal, Switzerland; Jakobsberg, Sweden; Waldau, Bavaria.

*For a full description of the uses and economic occurrences of feldspar in the United States, see Bastin, Bulletin 420, United States Geological Survey.

TRICLINIC FELDSPARS

MICROCLINE, KAlSi_3O_8 .

Triclinic, pinacoidal class. $a : b : c = 0.65 : 1 : 0.55$, $\alpha = 90^\circ 30'$, $\beta = 116^\circ$, $\gamma = 90^\circ$ (approximately). Crystals resemble those of orthoclase in habit, angles, and crystal form. The angle between the basal and brachypinacoids varies from $90^\circ 15'$ to $90^\circ 35'$, usually about $90^\circ 30'$. Crystals are generally large and only apparently simple individuals, being in reality polysynthetic twins according to the albite and pericline laws. In the first law the brachypinacoid acts as the twinning plane, in the second the crystallographic b axis is the twinning axis. Basal sections of polysynthetic twins according to these two laws show under the microscope a characteristic grating-like structure.* This structure is not observed on the other feldspars and is, hence, very characteristic of microcline. These polysynthetic twins are sometimes further twinned according to the Karlsbad, Baveno, and Manebach laws, so common on orthoclase. Occurs also in cleavable and compact granular masses.

Basal and brachypinacoidal cleavages at an angle of about $90^\circ 30'$, also indistinct prismatic cleavages. Uneven fracture. Hardness 6 to 6.5. Specific gravity 2.54 to 2.57. Vitreous luster, inclining to pearly on the basal pinacoid. White, cream yellow, yellowish gray, red, and green in color. Green varieties, often bright verdigris green, are called *amazonite* or *amazonstone*. Transparent to translucent.

KAlSi_3O_8 . Usually contains some Na_2O . Chemical composition and behavior are in general the same as for orthoclase.

Occurrence similar to that of orthoclase, but not common in eruptive rocks. Smoky quartz, topaz, and phenacite are typical associates. Commonly in regular intergrowths with orthoclase, albite, and other feldspars. Some localities are Striegau, Silesia; Arendal, Norway; Magnet Cove, Ark. Amazonstone occurs in excellent crystals in the Ural Mountains, Greenland, and in the Pike's Peak district, Colo.

ANORTHOCASE, Soda Microcline, $(\text{Na},\text{K})\text{AlSi}_3\text{O}_8$.

Triclinic, pinacoidal class. $a : b : c = 0.6466 : 1 : 0.5522$, $\alpha = 90^\circ 30'$, $\beta = 116^\circ 18'$, $\gamma = 90^\circ$. Crystals are similar to those of the ordinary feldspars. Twins according to the common laws of orthoclase, also polysynthetic twinning according to the albite and pericline laws. General physical properties like those of orthoclase. Sometimes shows a blue opalescence.

$(\text{Na},\text{K})\text{AlSi}_3\text{O}_8$. Often considered an isomorphous mixture of albite and ortho-

* This can be seen in Figure 138a.

class material in the proportion of 2 to 4.5 parts of albite to one of orthoclase. Some CaO is always present.

Occurs in the lavas of the Island of Pantelleria, south of Sicily; in the augite syenites and "Rhomben-porphyr" of southern Norway; in the rhyolite of Obsidian Cliff, Yellow Stone Park.

ALBITE-ANORTHITE SERIES

(Plagioclase Feldspars)

These feldspars are sometimes called the *soda-lime feldspars*, and also, as already indicated on page 260, the typical *plagioclases* in the narrower sense. They are regarded as constituting a continuous isomorphous series with albite and anorthite as the end members. According to Tschermak, the chemical composition of the various members of the series may be indicated as follows:

Albite, $\text{NaAlSi}_3\text{O}_8$, ...	(Ab),
Oligoclase, ...	Ab Ab_3An_1 ,
Andesine, ...	Ab_3An_1 Ab_1An_3 ,
Labradorite, ...	Ab_1An_1 Ab_1An_3 ,
Bytownite, ...	Ab_1An_3 An,
Anorthite, $\text{CaAl}_2\text{Si}_2\text{O}_8$, ...	(An).

The following table, based upon the calculations of Tschermak and adapted from Klockmann, shows clearly the progressive changes in chemical composition, specific gravity, and certain extinction angles.

Name	Composition	% of Anorthite	SiO_2	Al_2O_3	CaO	Na_2O	Specific Gravity	Extinction Angles	
								Basal Pinacoid	Brachy Pinacoid
Albite	Ab	0	68.6	19.6	—	11.8	2.605	+ 4°30'	+19°
Oligoclase	Ab_3An_1	26	61.9	24.2	5.2	8.7	2.659	+ 1°4'	+ 4°36'
Andesine	Ab_1An_1	51.5	55.4	28.5	10.4	5.7	2.694	— 5°10'	—16°
Labradorite	Ab_1An_3	76.1	49.1	32.8	15.3	2.8	2.728	—17°40'	—29°28'
Bytownite	An	96	46.6	34.4	17.4	1.6	2.742	—27°33'	—33°29'
Anorthite		100	43.0	36.9	20.1	—	2.765	—37°	—36°

The intermediate members are important constituents of many igneous rocks and more common than albite or anorthite. They are rarely well crystallized, but can usually be recognized by the striations on the basal pinacoid, due to multiple twinning according to the albite law. The various members of the series are not easily differentiated macroscopically.

ALBITE, Soda Feldspar, $\text{NaAlSi}_3\text{O}_8$.

Triclinic, pinacoidal class. $a : b : c = 0.6330 : 1 : 0.5573$, $\alpha = 94^\circ 5'$, $\beta = 116^\circ 27'$, $\gamma = 88^\circ 7'$. Crystals are usually not large and often similar in development to those of orthoclase, figure 139, or tabular and elongated parallel to the b axis, figure 140. These are called the *albite* and *pericline* habits, respectively. Twins are very common, single individuals being rare. The twinning laws are: (1) *Albite law*, the brachypinacoid is the twinning plane. Simple contact and repeated twins, figures 141 and 142. Polysynthetic twins show striations on the basal pinacoid, which extend parallel to the edge between the basal and brachypinacoids. (2) *Pericline law*, the b axis is the twinning axis. Figure 143 shows a simple contact twin according to this law, showing the characteristic rhombic cross-section. Polysynthetic twins have fine striations on the brachypinacoid. The three twinning laws of orthoclase, page 260, are also occasionally observed. Albite also occurs in lamellar and granular masses, the laminae being often curved and divergent.

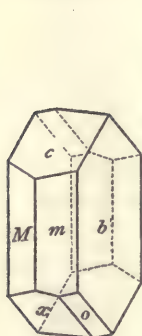


FIG. 139

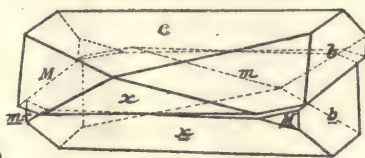


FIG. 140

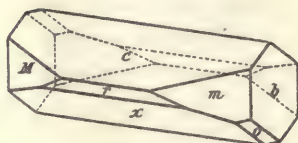


FIG. 141

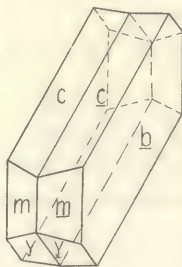


FIG. 142



FIG. 143

Perfect basal and brachypinacoidal cleavages, imperfect parallel to the prism faces. The angle between the basal and brachypinacoids is $86^\circ 24'$. Brittle. Hardness 6 to 6.5. Specific gravity 2.6 to 2.65, pure albite 2.605. Vitreous luster, inclining to pearly on the cleavages. The basal pinacoid often shows a bluish opalescence, especially on the varieties called *peristerite* and *moonstone*. Transparent to translucent. Usually colorless; rarely colored, gray, bluish, reddish, and greenish.

$\text{NaAlSi}_3\text{O}_8$. Sodium is generally replaced by some potassium and calcium. Rarely free from calcium. Albite contains more SiO_2 than any of the feldspars, namely 68.6%, see table on page 265. Fuses to a colorless or white glass. Colors the flame yellow. Not acted upon by acids.

As a rock mineral, albite is not as abundant as the other plagioclases,



but occurs, nevertheless, in many gneisses and other crystalline schists, in granites, diorites, trachytes, and other eruptive rocks. Crystals are found in the cracks and crevices of silicate rocks, and more rarely in limestones and dolomites. Some of the associates of albite are chlorite, titanite, adularia, axinite, beryl, tourmaline, quartz, chrysoberyl, columbite, and apatite. Found often in regular intergrowth with orthoclase, as perthite, page 262.

Some important localities are:— the St. Gotthard district, Switzerland; Zillerthal, Pfitsch, and Schmirn, Tyrol; Rauris, Salzburg; Baveno, Italy; Hirschberg and Striegau, Silesia; Roc Tourne, Savoy, and Dauphine, France; Arendal and Snarum, Norway; Cornwall, England; Mursinka, Ural Mountains; Pike's Peak, Colo.; Amelia Court House, Va.; Unionville, Chester County, Pa.; Haddam, Middletown, and Branchville, Conn.; Chesterfield, Mass.; Paris, Me.; various places in New York, New Hampshire, North Carolina, and elsewhere.

Moonstone is often used for gem purposes.

Oligoclase, Soda-lime Feldspar.

Triclinic, pinacoidal class. For elements of crystallization, see page 259. Crystals are columnar parallel to the c axis, or tabular parallel to the basal or brachypinacoids. Twins according to the Karlsbad, albite, or pericline laws. Crystals are, however, not very common. Usually observed in compact, cleavable, or granular masses.

Basal and brachypinacoid cleavages making an angle of $86^{\circ}32'$. Conchoidal to uneven fracture. Brittle. Hardness 6 to 6.5. Specific gravity 2.65 to 2.67. Vitreous, pearly, or waxy to greasy luster. Transparent to subtranslucent. White or colorless, also grayish or reddish white, gray green, or green. *Aventurine oligoclase* or *sunstone* is a variety containing disseminated scales of probably hematite or goethite, giving rise to yellowish or reddish reflections.

Ab...Ab₃An₁, for the percentage composition see the table on page 259. Fuses to a clear or blebby glass. Only slightly acted upon by acids.

Occurs as a rock mineral in some of the acid silicate rocks, such as granites, gneisses, syenites, diorites, porphyries, andesites, and trachytes. Some associates are orthoclase, quartz, tourmaline, epidote, garnet, pyrrhotite, corundum, augite, and calcite. Found at Arendal and, as sunstone at Tvedstrand, Norway; Bodenmais, Bavaria; Mount Vesuvius; Lake Baikal; Pargas, Finland; Ural Mountains; Bakersville, N. C.; Danbury and Haddam, Conn.; Fine and Macomb, St. Lawrence County, N. Y.; Mineral Hill and Unionville, Pa.; Chester, Mass.

Aventurine or sunstone is used for gem purposes.

ANDESINE.

Triclinic, pinacoidal class. For the elements of crystallization, see page 259. Generally in cleavable and granular masses, crystals which are similar to those of oligoclase being very rare.

Perfect basal and brachypinacoidal cleavages, making an angle of $86^{\circ} 14'$. Hardness 6. Specific gravity 2.69. Vitreous luster, inclining to pearly. Colorless, white, greenish, gray, yellowish, to flesh red.

$\text{Ab}_2\text{An}_1 \dots \text{Ab}_1\text{An}_1$. Fuses more easily than albite. Occurs especially in andesites, diorites, and dacites. Found in the Andes Mountains, South America; Bodenmais, Bavaria; Ekaluit, Greenland; Island of Sardinia; Finland; L'Esterel, France; Toluca, Mexico; Chateau Richer, Montmorency County, Quebec, Canada; Sanford, Me.; Telham, Mass.; Clay County, N. C. Not so abundant as oligoclase.

Labradorite, Lime-soda Feldspar.

Triclinic, pinacoidal class. For the elements of crystallization see page 259. Well developed crystals are rare, their habit is usually tabular parallel to the brachypinacoid. Twins according to the various laws given for albite. Generally observed in cleavable, granular, or cryptocrystalline masses.

Perfect basal and brachypinacoid cleavages, making an angle of $86^{\circ} 4'$. Hardness 5 to 6. Specific gravity 2.7 to 2.74. Translucent to subtranslucent. Gray, brown, or greenish in color, often showing a beautiful play of colors,—yellowish, bluish, greenish, or reddish—on the brachypinacoid. This *labradorescence* is due to the fine lamellar structure or to microscopic inclusions, or to both. Uncolored streak.

$\text{Ab}_1\text{An}_1 \dots \text{Ab}_1\text{An}_3$. Fuses to a colorless or white glass, coloring the flame yellow. Decomposed with difficulty by hydrochloric acid.

Occurs in basic igneous rocks, such as gabbro, norite, basalt, diabase, and andesite. Found on Mount Aetna; Transylvania; Finland; Sweden; Greenland; varieties showing an excellent labradorescence are common at various places on the coast of Labrador, also on the Isle of St. Paul; Adirondack Mountains, N. Y.; Wichita Mountains, Ark.; various places in Maryland, North Carolina, and British Columbia.

Varieties showing the play of colors are used for ornamental purposes and are sometimes termed *labrador spar*.

BYTOWNITE.

Triclinic, pinacoidal class. For the elements of crystallization see page 259. Very similar to labradorite in properties and occurrence, and includes certain feldspars formerly described as anorthite. Some localities are Bytown, Canada; Neurode, Silesia; Iceland; Hartz Mountains; Island of Corsica. Is not as abundant as labradorite.

Anorthite, Lime Feldspar, $\text{CaAl}_2\text{Si}_2\text{O}_8$.

Triclinic, pinacoidal class. $a : b : c = 0.6347 : 1 : 0.5501$, $a = 93^{\circ} 13'$, $\beta = 115^{\circ} 55'$, $\gamma = 88^{\circ} 48'$. Crystals are prismatic and elongated parallel to either the c or b axes, tabular parallel to the basal pinacoid. Crystals are often very complex. Twins according to the several laws indicated for albite. Occurs also in cleavable, granular, or lamellar masses.

Perfect basal and brachypinacoidal cleavages making an angle of 85°

50'. Conchoidal to uneven fracture. Brittle. Hardness 6 to 6.5. Specific gravity 2.7 to 2.8. Transparent to translucent. Uncolored streak. Colorless, white, bluish, yellowish, reddish, or rose red. Vitreous luster, inclining to pearly on the cleavages.

$\text{CaAl}_2\text{Si}_2\text{O}_8$. Generally contains small amounts of Na_2O , K_2O , MgO , and Fe_2O_3 . The presence of H_2O is indicative of some alteration. Fuses with difficulty to a colorless glass. Decomposed by hydrochloric acid with a separation of gelatinous silica.

Anorthite occurs as an important constituent of basic silicate rocks, such as gabbros, diorites, and basalts; also as a contact mineral and in meteorites. Excellent crystals have been observed in the ejectamenta of Mount Vesuvius; Island of Miyake, Japan; Iceland; Monzoni district, Tyrol; Transylvania; Ural Mountains; Pikesville, Md.; Franklin Furnace, N. J.

CELSIAN, $\text{BaAl}_2\text{Si}_2\text{O}_8$.

Triclinic, pinacoidal class. For the elements of crystallization see page 259. Found in compact masses with basal and brachypinacoidal cleavages at an angle of $89^\circ 36'$. Hardness 6 to 6.5. Specific gravity 3.37. Contains about 39% BaO . Colorless. Occurs associated with schefferite and other manganese minerals at Jakobsberg, Sweden.

SCAPOLITE GROUP

The members of this group are similar to the triclinic feldspars in chemical composition, being aluminium silicates containing either Na_2O or CaO . Tschermak believes that the composition of the group can best be explained by assuming the isomorphous mixing of two end members, which are analogous to albite and anorthite of the plagioclase group. These compounds are

Meionite,

$\text{Na}_4\text{Al}_3\text{Si}_5\text{O}_{24}\text{Cl}(\text{Ma})$.

Marialite,

$\text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{25}(\text{Me})$.

The composition of the intermediate members may be expressed by the general formula $m\text{Me} + n\text{Ma}$. It must be pointed out, however, that aside from the constituents indicated in the formulas given above, small amounts of K_2O , CO_2 , SO_3 , MgO , and H_2O are usually present. The role these constituents play is not clearly understood. The soda varieties contain the largest percentages of SiO_2 and chlorine. They also have the lowest specific gravity, refringence and birefringence, and are least soluble in acids.

The names *scapolite* and *wernerite* have been applied quite generally to many members of the group and, hence, the general properties of the group will be given under that caption.

SCAPOLITE, Wernerite, $n\text{Na}_4\text{Al}_3\text{Si}_9\text{O}_{24}\text{Cl} + m\text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{25}$.

Tetragonal bipyramidal class. The axial ratio varies between 1 : 0.4393 for meionite and 1 : 0.4425 for marialite. Thick, coarse, prismatic crystals, often large with dull and uneven faces. The common forms are the prisms of the first and second orders *m* and *a*, unit bipyramids of the same orders *o* and *d*, and the bipyramid of the third order *s*, see figures 144 and 145. Occurs also in fibrous, coarse to fine granular, and compact masses.

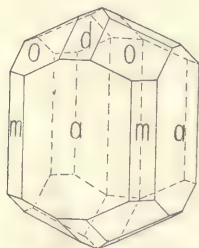


FIG. 144

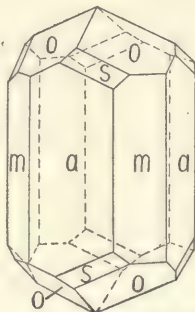


FIG. 145

Perfect prismatic cleavages. Conchoidal fracture. Brittle. Hardness 5 to 6. Specific gravity 2.566 for marialite and 2.764 for meionite. Vitreous luster, inclining to pearly and greasy. Colorless, white, gray, greenish, bluish, or reddish. Colorless streak.

The chemical composition is variable, as explained above. The amount of SiO_2 commonly present varies between 40.45 and 64%. In some cases as much as 4.2% of chlorine has been noted. Some of the scapolites are readily decomposed by hydrochloric acid, others not. All are quite easily fusible with intumescence. The scapolites alter to kaolin, epidote, muscovite, biotite, albite, and various zeolites.

Three varieties are commonly differentiated:

(1) *Marialite*, $\text{Na}_4\text{Al}_3\text{Si}_9\text{O}_{24}\text{Cl}$. Always contains some CaO and is not decomposed by acids. Usually as small, clear, and colorless crystals. The common scapolites are cloudy or dull, and more or less colored; sometimes rather large.

(2) *Missonite*, Dipyre , Me_2Ma_1 to Me_1Ma_2 . Partially decomposed by acids. Small, prismatic, whitish crystals, often clear.

(3) *Meionite*, $\text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{25}$. Completely soluble in hydrochloric acid. Small, colorless and glassy, or milky white crystals, often without distinct terminal faces.

The scapolite minerals are generally the result of metamorphism. Com-

mon in granular limestones near the contact with igneous rocks, also in crystalline schists and volcanic ejectamenta. May also occur independently. The characteristic associates are the pyroxenes, apatite, garnet, titanite, zircon, biotite, and hornblende. Some localities are Arendal, Norway; Pargas, Finland; Hafnerzell, near Passau, Bavaria; Laacher See, Rhenish Prussia; Mount Vesuvius; Ripon and Grenville, Quebec, and various places in Ontario, Canada; Bolton, Mass.; various places in Northern New York; Franklin and Newton, N. J.

SARCOLITE, $\text{Na}_2\text{Ca}_8\text{Al}_6\text{Si}_9\text{O}_{38}$, is somewhat related to the scapolites. Tetragonal bipyramidal class. $a : c = 1 : 0.4183$. Occurs in small reddish white or flesh red, transparent to translucent crystals in the ejectamenta of Mount Vesuvius. Hardness 5.5 to 6. Specific gravity 2.54 to 2.93. Resembles analcite.

EUDIDYMITE GROUP

The group consists of the two minerals eudidymite and epididymite, having the same chemical composition $\text{HNaBeSi}_3\text{O}_8$.

EUDIDYMITE, $\text{HNaBeSi}_3\text{O}_8$, monoclinic prismatic class. $a : b : c = 1.7107 : 1 : 1.1071$, $\beta = 93^\circ 45\frac{1}{2}'$. Occurs in simple and twinned, tabular crystals. Colorless, transparent to translucent. Vitreous to pearly or silky luster. Basal cleavage. Hardness 6. Specific gravity 2.553. Easily fusible to a colorless or white glass. Partially decomposed by acids. Occurs sparingly in nepheline syenite on the island of Ovre Arö, Norway.

EPIDIDYMITE, $\text{HNaBeSi}_3\text{O}_8$. Orthorhombic bipyramidal class. $a : b : c = 1.7274 : 1 : 1.068$. Simple crystals are usually elongated parallel to the a axis; often as penetration twins. Properties are similar to those of eudidymite. Found in southern Greenland associated with eudialyte, arfvedsonite, neptunite, albite, and zircon. A rare mineral.

TITANITE GROUP

Here a number of silicates containing titanium or zirconium will be described of which titanite is the most important. There are no close crystallographic or chemical relationships to be noted between them.

TITANITE, Sphene, Grothite, CaTiSiO_6 .

Monoclinic, prismatic class. $a : b : c = 0.4272 : 1 : 0.6575$, $\beta = 94^\circ 38'$. The habit varies greatly. Disseminated crystals are generally wedge or envelope shaped, while attached crystals are apt to be tabular or prismatic,

see figures 146 and 147. The common forms are the basal pinacoid c , unit prism m , unit and modified ($m = 1/2$) negative hemiorthodomes y and x , clinodome r , and the hemipyramid $n(2a : b : 2/3c)$. In figure 147 the crystal has been placed so that the hemipyramid n is vertical, emphasizing the prismatic development parallel to these faces. Contact (Figure 148) and penetration twins (sometimes cruciform) with the basal pinacoid as the twinning plane are rather common. Occurs sometimes compact and massive, more rarely lamellar.

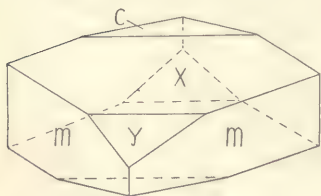


FIG. 146

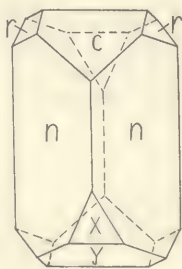


FIG. 147



FIG. 148

Distinct prismatic and domatic cleavages. Conchoidal fracture. Brittle. Hardness 5 to 5.5. Specific gravity 3.4 to 3.6. Transparent or translucent to opaque. Vitreous luster, inclining to adamantine or greasy. Yellow, green, brown, reddish brown, red, and black in color. The transparent or translucent yellow, greenish, and other light colored varieties are called *sphene*, the brown varieties *grothite*.

CaTiSiO_5 . Commonly considered the calcium salt of the dimetasilicic acid $\text{H}_2\text{Si}_2\text{O}_5$, in which one atom of silicon has been replaced by titanium. May also contain some FeO or MnO . *Yttrotitanite* contains aluminium, iron, and the elements of the yttrium group. Fuses with intumescence on the edges to a dark colored glass. Only partially decomposed by hydrochloric acid, completely by sulphuric and hydrofluoric acids. Titanite alters to rutile, octahedrite, brookite, perovskite, magnetite, or ilmenite. *Leucoxene* and *titanomorphite* are fine granular or fibrous aggregates of titanite, alteration products of various titanium minerals.

Titanite occurs disseminated as an important accessory constituent of many igneous rocks, especially hornblende granites, syenites, nepheline syenites, trachytes, phonolites, and diorites; also in crystalline schists and granular limestones. It is found attached in the cracks and cavities in granite, gneiss, and various schists. The common associates are the amphiboles, pyroxenes, apatite, zircon, scapolite, chlorite, and iron minerals. Some localities are Laacher See, Rhenish Prussia; many places in Switzerland and Ty-

rol, especially in the St. Gotthard district, Tavetsch, Zillerthal, and Pfitschthal; Arendal, Norway; Nordmark, Sweden; Ural Mountains; Tremadoc, North Wales; Grenville, Quebec, and Eganville, Renfrew County, Ontario, Canada; Sanford, Me.; Bolton and Lee, Mass.; Diana, Lewis County, Monroe, Orange County, and elsewhere in New York; Franklin Furnace, N. J.; Bucks County, Pa.; Magnet Cove, Ark.

Titanite is sometimes used as a gem.

ZIRKELITE, $\text{Ca}(\text{Zr,Ti})_2\text{O}_6$, is similar to titanite in general composition but contains zirconium in place of silicon. Occurs in small black crystals belonging to the cubic system in the pyroxenites of Jacupiranga, Province of Sao Paulo, Brazil. Hardness 5.5. Specific gravity 4.74. Resinous luster.

TSCHEFFKINITE is an alteration product of more or less uncertain composition. Is essentially a titano-silicate of aluminium, cerium elements, iron, and beryllium. Amorphous. Black. Vitreous luster. Hardness 5 to 5.5. Specific gravity 4.5 to 4.55. Occurs in the Ural Mountains; southern India; Nelson and Bedford counties, Virginia.

CATAPLEIITE, $\text{H}_4\text{Na}_2\text{ZrSi}_3\text{O}_{11}$.

Monoclinic at ordinary temperatures but at 140° it passes over into an hexagonal modification. Its behavior is similar to that of tridymite. Hardness 6. Specific gravity 2.8. Light yellow to yellowish brown in color, also blue, gray, reddish, and white. Transparent to opaque. May contain calcium replacing some sodium. Found in Norway and Greenland.

ELPIDITE, $\text{H}_6\text{Na}_2\text{ZrSi}_6\text{O}_{18}$. Orthorhombic. Columnar and felty fibrous masses. White to brick red in color. Pearly luster. Occurs at Igaliko, southern Greenland.

EUDIALYTE, $\text{Na}_{13}(\text{Ca,Fe})_6(\text{Si,Zr})_{20}\text{O}_{52}\text{Cl}$.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 2.1116$. Columnar or tabular crystals, sometimes rather large. Also in granular or reniform masses. Red to brown in color. Uncolored streak. Basal cleavage. Translucent. Conchoidal to splintery fracture. Hardness 5 to 6. Specific gravity 2.9 to 3.1. Fuses easily with intumescence to dark green blebby mass, coloring the flame yellow. Decomposed by acids with separation of silica, the solution reacts for zirconia. Occurs in nepheline syenites at Kangerdluarsuk, Greenland; Kola peninsula, Russian Lapland; Magnet Cove, Ark. *Eucolite* is a brownish variety occurring at Langesund fiord, Norway.

STEENSTRUPINE, a thoro-silicate of La, Di, Y, Na, Be, Pb, Nb, and Ce. Occurs at Kangerdluarsuk, Greenland.

DYSANALYTE, may be considered as having the general formula $6\text{RTiO}_3 \cdot \text{RNb}_2\text{O}_6$, where R is Ca, Fe, Mn, Ce, and Na. Occurs in small, black crystals in granular limestone at Voigtsburg, Kaiserstuhl, Baden. Formerly called perovskite. Found also on Mount Vesuvius, Italy.

PYROCHLORE is similar to dysanaltyte, the niobate predominating however. Occurs in small octahedral crystals and in grains. Octahedral cleavage. Conchoidal fracture. Hardness 5 to 5.5. Specific gravity 4.2 to 4.36. Brown, reddish, or blackish brown in

color. Vitreous to resinous luster. Occurs in nepheline syenite at Laurvik, Norway; Miask, Ural Mountains.

PYRRHITE is closely related to pyrochlore and is found in small, yellow red octahedrons at San Miguel, the Azores, and in the Laacher See district, Rhenish Prussia.

POLYMIGNITE, $\text{Ca}_3(\text{CeO})_4(\text{Ti}_2\text{O}_5)_5\cdot\text{Ca}(\text{NbO}_3)_2$. Titanium may be replaced by considerable zirconium, cerium by yttrium, and calcium by small amounts of iron, manganese, potassium, and sodium. Orthorhombic. Long columnar crystals, striated vertically. Conchoidal fracture. Hardness 6 to 6.5. Specific gravity 4.75 to 4.85. Black in color. Occurs in zircon syenite at Fredriksvärn, Norway.

AESCHYNITE is similar to polymignite in composition, but contains thorium and at times helium. Orthorhombic. Columnar and tabular, but imperfectly developed, crystals; also massive. Iron black to brown in color. Yellow brown streak. Hardness 5 to 6. Specific gravity 4.93 to 5.17. Occurs at Miask, Ural Mountains; Hitterö, Norway; Königshain, Silesia.

POLYCRASE is essentially $(\text{Ca},\text{Fe})_4\text{Y}_4(\text{UO}_2)\text{Ti}_{12}\text{O}_{38}\cdot 2\text{Y}(\text{NbO}_3)_3$. Orthorhombic. Six-sided, thin tabular crystals, sometimes rather large. Striated vertically. Color black. Streak grayish brown. Opaque, translucent in thin splinters. Hardness 5 to 6. Specific gravity 4.7 to 5.1. Vitreous to resinous luster. Found at Hitterö, Norway; North and South Carolina.

EUXENITE is essentially a titanate and niobate of yttrium, erbium, and cerium, containing uranium, iron, and helium. Orthorhombic, but crystals are rare. Commonly found massive. Hardness 6.5. Specific gravity 4.6 to 5. Color pitch black. Reddish brown streak. Opaque. Submetallic to greasy vitreous luster. Occurs at Arendal and Hitterö, Norway.

BENITOITE, $\text{BaTiSi}_3\text{O}_9$.

Hexagonal, ditrigonal bipyramidal class. $a : c = 1 : 0.7344$. Crystals are ditrigonal bipyramidal and thick tabular in habit. Pale to deep blue in color, rarely colorless. Transparent. Hardness 6.5. Specific gravity 3.65. Conchoidal fracture. Very imperfect pyramidal cleavage.

$\text{BaTiSi}_3\text{O}_9$. Although commonly interpreted as a titano-silicate, it may be considered, however, as a metasilicate of barium and titanium. Fuses easily to a transparent glass. Practically insoluble in hydrochloric acid. Attacked by hydrofluoric acid and readily dissolved by fused sodium carbonate.

Occurs associated with natrolite and neptunite in San Benito county, Cal.

Benitoite is used for gem purposes.

LORENZENITE, $\text{Na}_2\text{Si}_2(\text{Ti},\text{Zr})_2\text{O}_9$.

Orthorhombic, bipyramidal class. $a : b : c = 0.6042 : 1 : 0.3592$. Small, acicular crystals with distinct brachyprismatic cleavage. Brittle. Hardness 6 to 6.25. Specific gravity 3.42. Brilliant adamantine luster. Colorless, inclining to violet or brown. Transparent to translucent. Fuses easily to a black globule. Not attacked by acids. It occurs, associated with aegirite, microcline, albite, and arfvedsonite in pegmatite at Narsarsuk, southern Greenland.

PETALITE, Castorite, $\text{LiAl}(\text{Si}_2\text{O}_5)_2$.

Monoclinic, prismatic class. $a : b : c = 1.1535 : 1 : 0.7441$, $\beta = 112^\circ 26'$. Columnar or tabular crystals. Usually compact, fine granular, or foliated masses.

Perfect basal and imperfect domatic cleavages. Imperfect conchoidal fracture. Brittle. Specific gravity 2.4 to 2.5. Hardness 6 to 6.5. Vitreous luster, inclining to pearly. Transparent to translucent. Colorless, white, gray, reddish or greenish white. Colorless streak.

$\text{LiAl}(\text{Si}_2\text{O}_5)_2$. Sodium and potassium may replace some of the lithium. Phosphoresces when heated. Fuses on the edges and colors the flame red. Soluble in hydrofluoric acid but not in the other common acids.

The common associates are spodumene, tourmaline, scapolite, lepidolite, and quartz. It is found in the magnetite deposits of Utö, Sweden; Island of Elba; Bolton, Mass.; Peru, Me.

NEPTUNITE, $(\text{Na},\text{K})_2(\text{Fe},\text{Mn})(\text{Si},\text{Ti})_5\text{O}_{12}$.

Monoclinic, prismatic class. $a : b : c = 1.3164 : 1 : 0.8075$, $\beta = 113^\circ 38'$. Prismatic crystals with vertical striations. Vitreous luster, inclining to metallic; on cleavages somewhat greasy. Black in color. Cinnamon brown streak. Distinct prismatic cleavage. Hardness 5 to 6. Specific gravity 3.234. Fuses quite easily to a black globule. Not attacked by the common acids. Easily decomposed by fusion with the alkali carbonates. Occurs with aegirite in the syenite of Igaliko, southern Greenland, and with natrolite and benitoite in San Benito County, Cal.

MILARITE, $\text{HKCa}_2\text{Al}_2(\text{Si}_2\text{O}_5)_6$.

Pseudo-hexagonal, $a : c = 1 : 0.6620$. At ordinary temperatures biaxial and apparently made up of orthorhombic trillings, becomes uniaxial on heating. Specific gravity 2.5 to 2.6. Hardness 5 to 6. Vitreous luster. Colorless to pale green. Conchoidal fracture. Transparent. Fuses easily and is partially decomposed by acids. Occurs with smoky quartz, adularia, apatite, chabasite, titanite, and chlorite in granite at Gletsch and Val Giuf, Switzerland.

ZEOLITES

The general term *zeolite* includes a number of important, hydrated silicates, which usually crystallize exceedingly well and are closely related to each other in general chemical composition, in many physical and chemical properties, and also in methods of formation and occurrence. Crystallographically and optically, they are commonly very complex.

The zeolites are for the most part either hydrated ortho-, meta-, or polysilicates of aluminium, bearing striking resemblances to the minerals of the nephelite, leucite, and feldspar groups. In many cases part of the aluminium may be replaced by Na_2O , CaO , or K_2O , also by BaO , SrO , or MgO , but never by the heavier metals. In one case, that of apophyllite, aluminium does not enter at all into the chemical composition.

All the zeolites are quite readily decomposed by hydrochloric acid, many gelatinizing. They fuse easily with a characteristic intumescence. The water may be driven off at different temperatures. In some cases it is so loosely held that it escapes in a dry atmosphere, in others comparatively high temperatures, even ignition, are necessary to remove all traces. Some dehydrated zeolites take up water again when exposed to moisture. The loss of water causes important changes in the optical properties.

The specific gravity of the various members of the group is relatively low and varies from 2.0 to 2.4. The zeolites are all what may be called comparatively soft minerals, the hardness varying from 3.5 to 5.5. All are generally colorless, transparent to translucent, and highly vitreous; sometimes however, more or less colored, due to the presence of various pigments.

The zeolites are secondary minerals, the result of the decomposition of the chemically related, primary minerals, such as nephelite, leucite, sodalite, and the feldspars, especially the plagioclases. They are never found disseminated, but almost always in cracks, crevices, and cavities in basic eruptive, igneous rocks, such as basalt, diabase, and phonolite; more rarely in granite and crystalline schists, and sometimes with ore deposits. Zeolites are also sometimes deposited from hot springs, although high temperatures are not essential to their formation. All zeolites decompose rather easily and tend to form calcium carbonate and kaolin. Their common associates are calcite, datolite, prehnite, and pectolite.

ORTHOSILICATES

Thomsonite, Comptonite, $2(\text{Ca}, \text{Na}_2)\text{Al}_2(\text{SiO}_4)_2 \cdot 5\text{H}_2\text{O}$.

Orthorhombic, bipyramidal class. $a : b : c = 0.9932 : 1 : 1.0066$. Vertically striated prismatic crystals, generally arranged in sheaf- or fan-like groups. The prism angle is $90^\circ 26'$. At times as heart-shaped twins, with the unit prism as the twinning plane. Also compact and in spherical concretions.

Perfect brachy- and imperfect macropinacoidal cleavages. Uneven fracture. Brittle. Vitreous luster, inclining to pearly on the cleavages. Transparent to translucent. Colorless to white, grayish, yellowish, brownish, and reddish. A greenish variety is called *lintonite*. The colors are often banded resembling agate. Uncolored streak. Hardness 5 to 5.5. Specific gravity 2.3 to 2.4. Gelatinizes with acids. Intumescs briskly, fusing to a white enamel.

Occurs with other zeolites and prehnite in amygdaloidal and other igneous rocks. Some localities are Kaaden, Hauenstein, and elsewhere, Bohemia; Pflasterkaute, near Eisenach, Thuringia; Brevik, Norway; Seisser Alp and in the Fassa valley, Tyrol; Kilpatrick, Scotland; Mount Vesuvius;

Fårö island, Sweden; Cyclopean islands, near Sicily; Iceland; Port George and Peter's Point, Nova Scotia; Table Mountain, Colo.; rather commonly in the amygdaloidal rocks of the Lake Superior district.

Sometimes cut and polished for gem and ornamental purposes.

HYDRONEPHELITE, $\text{HNa}_2\text{Al}_3(\text{SiO}_4)_3 \cdot 3\text{H}_2\text{O}$.

Probably hexagonal. Massive and radial fibrous aggregates. White, gray, or grayish black. Uneven fracture. Vitreous luster, sometimes dull. Hardness 4 to 6. Specific gravity 2.3 to 2.5. Fuses easily and gelatinizes with acids. Occurs in nepheline syenite at Litchfield, Me.; also found on the various islands in the Langesund fiord, Norway. *Ranite* is closely related to hydronephelite.

BASIC METASILICATES

A number of zeolites may be interpreted as being basic metasilicates, of which the members of the natrolite group are the most important.

NATROLITE GROUP

The minerals of this group are aluminium silicates containing either calcium, sodium, or barium, and two molecules of water. They crystallize in the monoclinic and orthorhombic systems. Mesolite and scolecite are monoclinic, edingtonite orthorhombic, while natrolite occurs in orthorhombic and monoclinic modifications. The chemical formulas and axial ratios of these minerals may be written as follows:

	a	:	b	:	c		β
Natrolite, $\text{Na}_2\text{Al}(\text{AlO})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$.	{ 1.0165	:	1	:	0.3599,		$90^\circ 5'$
	{ 0.9786	:	1	:	0.3536		

MESOLITE,

$\text{Na}_2\text{Al}(\text{AlO})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$.

$\text{CaAl}(\text{Al} \cdot 2\text{OH})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$.

	{ 0.9777	:	1	:	0.3226,		$92^\circ 6'$
Scolecite, $\text{CaAl}(\text{Al} \cdot 2\text{OH})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$.	0.9763	:	1	:	0.3433,		$90^\circ 42'$

EDINGTONITE,

$\text{BaAl}(\text{Al} \cdot 2\text{OH})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$.

0.9872 : 1 : 0.3367

Mesolite is considered an isomorphous mixture of natrolite and scolecite. The most abundant and important member of the group is natrolite.

Natrolite, Needle Zeolite, $\text{Na}_2\text{Al}(\text{AlO})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$.

Dimorphous. Usually orthorhombic, bipyramidal class. $a : b : c = 0.9786 : 1 : 0.3536$. Varieties containing small amounts of potassium are monoclinic, prismatic class, $a : b : c = 1.0165 : 1 : 0.3599$, $\beta = 90^\circ 5'$.

Orthorhombic crystals are long prismatic, nearly square (the prism angle is $91^{\circ} 15'$), or acicular, often radial, stellate, or interlacing groups or clusters. The monoclinic crystals are very similar to the orthorhombic and are quite rare. Occurs also in fibrous, granular, or compact masses.

Perfect prismatic cleavage. Brittle. Hardness 5 to 5.5. Specific gravity 2.2 to 2.3. Vitreous luster, inclining to pearly. Fracture uneven. Transparent to translucent. Colorless, white, flesh red, grayish, greenish, or yellowish.

$\text{Na}_2\text{Al}(\text{AlO})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$. Some Na_2O may be replaced by CaO or K_2O . Loses all of the water at 300° , which is absorbed again in a moist atmosphere. Fuses easily forming a colorless glass. Gelatinizes with acids.

Occurs in cracks and cavities in basic igneous rocks; also in granite, gneiss, and syenite. It is often an alteration product of lime-soda feldspars, nephelite, sodalite, cancrinite, and noselite. Some localities are Teplitz and Aussig, Bohemia; Fassathal and elsewhere, Tyrol; Fårö island, Sweden; Hohentwiel and Kaiserstuhl, Baden; Auvergne, France; various places in Norway, Ireland, and Scotland; Bergen Hill, N. J.; also in the Lake Superior district, and in the trap of Nova Scotia. Natrolite is found with other zeolites, with prehnite, and datolite.

Galacite, *bergmannite*, *sprenstein*, *brevicite*, *crocalite*, *fargite*, and *mesotype* are all varieties of natrolite.

MESOLITE.

An isomorphous mixture of the natrolite and scolecite molecules, usually in the ratio of 1 : 2. Monoclinic, prismatic class. For the elements of crystallization see page 277. Crystals are similar to those of scolecite in habit. Hardness 5. Specific gravity 2.2 to 2.4. White, porcelain-like, yellowish, or grayish. Occurs generally in very slender, acicular crystals, often arranged in tufts.

SCOLECITE, $\text{CaAl}(\text{Al} \cdot 2\text{OH})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$.

Monoclinic, domatic class. $a : b : c = 0.9763 : 1 : 0.3433$, $\beta = 90^{\circ} 42'$. Nearly square, slender prismatic crystals, very similar to those of natrolite; often acicular and in divergent groups. Generally twinned parallel to the orthopinacoid, causing vertical striations on the clinopinacoid. Also in compact, or radial fibrous or columnar masses.

Fairly perfect prismatic cleavage. Brittle. Conchoidal to uneven fracture. Vitreous luster, fibrous varieties are silky. Colorless, white, yellowish, or reddish. Transparent to translucent. Hardness 5 to 5.5. Specific gravity 2.2 to 2.4.

$\text{CaAl}(\text{Al} \cdot 2\text{OH})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$. About one-third of the water is held more firmly than the other, ignition being necessary to drive off the last traces. The chemical behavior is similar to that of natrolite.

Not nearly as common as natrolite. Occurs in the Maderanerthal and elsewhere, Switzerland; Iceland; Puna, East India; Black Lake, Megantic County, Quebec, Canada; Table Mountain, Colo.

EDINGTONITE, $\text{BaAl}(\text{Al}, 2\text{OH})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O}$.

Orthorhombic, bisphenoidal class. $a : b : c = 0.9872 : 1 : 0.3367$. Has been considered tetragonal. Small pyramidal crystals, also massive. Vitreous luster. Translucent to opaque. White, grayish white, reddish, or brown. White streak. Hardness 4 to 4.5. Specific gravity 2.7. Fuses with difficulty to a colorless glass. Occurs associated with harmotome in the Kilpatrick Hills, Scotland.

GANOPHYLLITE, $\text{Mn}_7(\text{AlO})_2(\text{SiO}_3)_8 \cdot 6\text{H}_2\text{O}$, is also to be considered as a basic metasilicate. Monoclinic, prismatic class. $a : b : c = 0.413 : 1 : 1.831$, $\beta = 93^\circ 21'$. Occurs in flat prismatic crystals, also in foliated masses. Hardness 4. Specific gravity 2.84. Vitreous luster. Brown in color. Reacts for manganese. Occurs in Harstig mine, Pajsberg, Sweden.

NORMAL METASILICATES

The most important normal metasilicate among the zeolites is analcite.

ANALCITE, $\text{Na}_2\text{Al}_2(\text{SiO}_3)_4 \cdot 2\text{H}_2\text{O}$.

Cubic, hexoctahedral class. Generally in well developed tetragonal tris-octahedrons ($m = 2$), figure 149, or sometimes in combination with the cube, figure 150. The other forms of this class are rarely observed. Crystals are usually quite small, but may be in some cases a foot in diameter. Also compact, granular, and earthy.

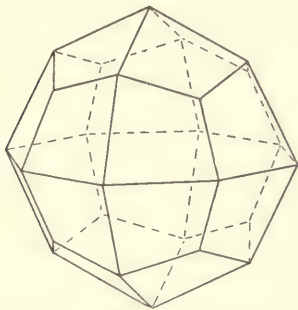


FIG. 149

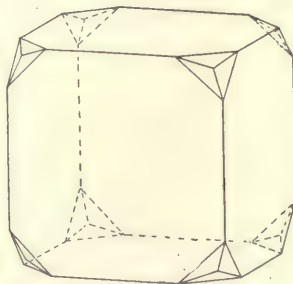


FIG. 150

No prominent cleavage. Uneven to conchoidal fracture. Brittle. Hardness 5 to 5.5. Specific gravity 2.2 to 2.4. Vitreous luster, sometimes dull. Transparent to nearly opaque. Colorless, white, greenish, grayish, yellowish, or reddish. White streak.

$\text{Na}_2\text{Al}_2(\text{Si}_3\text{O}_8)(\text{SiO}_4) \cdot 2\text{H}_2\text{O}$. This formula shows its chemical relationship to soda leucite. Fuses to a colorless, clear glass. Gelatinizes with acids.

Analcite is commonly a secondary mineral occurring with the other zeolites, calcite, datolite, native copper, magnetite, and prehnite in basalt, diabase, amygdaloids, granite, gneiss, and related rocks. In some cases it is thought to be primary, especially in analcite-basalts and analcite-phonolites. Some localities are the Cyclopean Islands, near Sicily; Seisser Alp and Fassathal, Tyrol; Aussig and Jabuken, Bohemia; Arendal, Norway; Brevik, Sweden; Andreasberg, Hartz Mountains; Fårö Island; Iceland; Kilpatrick Hills, Scotland; various places in Nova Scotia; Bergen Hill, N. J.; Lake Superior district; Table Mountain, Colo.

ACID METASILICATES

The following zeolites are to be interpreted as acid metasilicates because some of the water can only be driven off upon ignition. A portion of the water is, therefore, considered as being held by the silicon in the form of hydroxyl groups.

APOPHYLLITE, $\text{H}_{14}\text{K}_2\text{Ca}_8(\text{SiO}_3)_{16} \cdot 9\text{H}_2\text{O}$.

Ditetragonal bipyramidal class, $a : c = 1 : 1.2515$. Four distinct habits are common! (1) Long, square prisms, figure 151; (2) Pseudocubical, figure 152; (3) Pyramidal, figure 153; (4) Flat tabular, figure 154. The com-

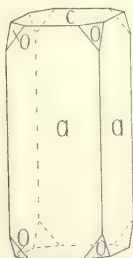


FIG. 151

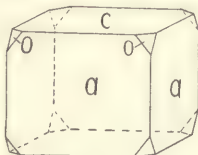


FIG. 152

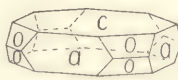


FIG. 154



FIG. 153

mon forms are the prism of the second order a , unit bipyramid of the first order o , and the basal pinacoid c . The prism faces are often brilliant but striated vertically, those of the basal pinacoid dull or rough, while the bipy-

ramid faces may be uneven. About sixty crystallographic forms have been recorded. Also occurs massive, and in granular and concentric aggregates.

Highly perfect basal, and imperfect prismatic cleavages. Uneven fracture. Brittle. Hardness 4.5 to 5. Specific gravity 2.3 to 2.4. Vitreous to pearly luster with a fish eye opalescence on the basal pinacoid. Usually transparent, rarely nearly opaque. Often shows anomalous optical properties.

$\text{H}_{14}\text{K}_2\text{Ca}_8(\text{SiO}_3)_{16} \cdot 9\text{H}_2\text{O}$. The composition is more or less uncertain. Usually contains about 5% of K_2O and up to 1.5% of fluorine. Some varieties evolve small amounts of ammonia when ignited. Only a small part of the water is given off at 100° , about one half between 240° and 260° , the remainder being liberated upon ignition. Exfoliates and fuses easily to a white enamel, coloring the flame violet. Decomposed by hydrochloric acid with a separation of silica. Alters to calcite, pectolite, and perhaps also kaolin.

Occurs with the other zeolites, and datolite, pectolite, native copper, magnetite, and calcite, as a secondary mineral in cracks and cavities in basalt and basic igneous rocks, also in granite, gneiss, etc. Found at St. Andreasberg, Hartz Mountains; Freiberg, Saxony; Seisser Alp and Fassathal, Tyrol; Fårö island, Sweden; Iceland; Greenland; Nova Scotia; Bergen Hill, N. J.; Table Mountain, Colo.; Lake Superior copper district.

FAUJASITE, $\text{H}_2(\text{Na}_2, \text{Ca}) \text{Al}_2(\text{SiO}_3)_5 \cdot 9\text{H}_2\text{O}$.

Cubic. Occurs in small octahedrons, sometimes twinned according to the spinel law. Vitreous to adamantine luster. Transparent to translucent. Colorless, white, or brown. Octahedral cleavage. Uneven fracture. Hardness 5.5 to 6. Specific gravity 1.9. Decomposed by hydrochloric acid. Fuses with intumescence. Becomes doubly refractive when a part of the water is driven off. Found on the Kaiserstuhl, Baden; Annerod and Grossenbuseck, Hessen; Daisy mica mine, Ottawa County, Quebec.

Heulandite, Stilbite in part, $\text{H}_4\text{CaAl}_2(\text{SiO}_3)_6 \cdot 3\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.4035 : 1 : 0.4293$, $\beta = 91^\circ 25'$. Usually more or less tabular parallel to the clinopinacoid. Since many crystals show striations similar to those on plagioclase, heulandite is sometimes considered triclinic and the crystals as polysynthetic twins. Occurs also in foliated and granular masses, and in globular forms.

Perfect clinopinacoidal cleavage. Uneven fracture. Brittle. Vitreous luster, pearly on the clinopinacoid. Transparent to translucent. Color white, gray, brown, and red. White streak. Hardness 3 to 4. Specific gravity 2.1 to 2.2.

$\text{H}_4\text{CaAl}_2(\text{SiO}_3)_6 \cdot 3\text{H}_2\text{O}$. Some of the calcium is usually replaced by strontium, also by potassium, sodium, and more rarely barium. Some of the water is driven off only when ignited. Exfoliates and fuses to a white glass. Decomposed by hydrochloric acid, but does not gelatinize.

Occurs with other zeolites in cavities in basalts, melaphyres, granites, gneisses, and in ore deposits. Found at Beruford, Iceland; Fårö island,

Sweden: Arendal and Kongsberg, Norway; Fassathal, Tyrol; Kilpatrick Hills, Scotland; Nova Scotia; Bergen Hill, N. J.; north shore of Lake Superior.

BREWSTERITE, $H_4(Sr,Ba)Al_2(SiO_3)_6 \cdot 3H_2O$.

Monoclinic, prismatic class. $a : b : c = 0.4046 : 1 : 0.4203$, $\beta = 93^\circ 4'$. A variety of heulandite containing about 9% of SrO and 6.5% of BaO. Tabular or prismatic crystals. White, yellowish, brownish, greenish, or grayish. Hardness 5. Specific gravity 2.1 to 2.5. Occurs at Strontian in Argyllshire, and Kilpatrick Hills, Scotland; Giant's Causeway, Ireland; France; Baden.

EPISTILBITE, $H_6Ca_2Al_4(SiO_3)_{11} \cdot 7H_2O$.

Monoclinic, prismatic class. $a : b : c = 0.4194 : 1 : 0.2881$, $\beta = 90^\circ 40'$. Similar in form to heulandite, but differs from it chemically. Occurs at Beruford, Iceland; Scotland; Margaretville, Nova Scotia.

MORDENITE, $(K_2,Na_2,Ca)Al_2Si_8O_{24} \cdot 7H_2O$. Monoclinic. Very similar to heulandite in crystal form. Occurs also in hemi-spherical, reniform, or cylindrical masses, often with a fibrous structure. Clinopinacoidal cleavage. Uneven fracture. Hardness 3 to 5. Specific gravity 2.1 to 2.2. Vitreous luster, inclining to pearly. Translucent. White, yellowish, or reddish. Found at Morden, Nova Scotia, and in the Hoodoo Mountains, Wyo.

INESITE, Rhodotile, $(Mn,Ca)(Mn.OH)_2Si_3O_8 \cdot H_2O$. Triclinic, pinacoidal class. $a : b : c = 0.9753 : 1 : 1.3208$, $\alpha = 92^\circ 18'$, $\beta = 132^\circ 56'$, $\gamma = 93^\circ 51'$. Crystals are not common, usually in fibrous and radiated aggregates and masses. Rose to flesh red in color. Hardness 6. Specific gravity 3. Vitreous luster. White streak. Occurs with manganese minerals in the Harstig mine, near Pajsberg, also at Jakobsberg, Sweden, and at Dillenburg, Nassau, Germany; Durango, Mexico.

NEUTRAL POLYSILICATES

The harmotome and chabazite groups consist of minerals which may be interpreted as being hydrated neutral polysilicates.

HARMOTOME GROUP

The members of this group crystallize in the monoclinic system, but owing to very complicated twinning are often pseudo-orthorhombic, pseudo-tetragonal, or even pseudo-cubical in development. Chemically, they are analogous to the plagioclases of the feldspar group, in that their fundamental composition may be interpreted as being due to an isomorphous mixture of two molecules somewhat similar to those of albite and anorthite.

	a	b	c	β
STILBITE , $(\text{Ca}, \text{Na}_2)\text{Al}_2\text{Si}_6\text{O}_{18} \cdot 6\text{H}_2\text{O}$.	0.7624	1	1.1939	$129^\circ 11'$
Phillipsite ,				
$\text{mCaAl}_2\text{Si}_6\text{O}_{18} \cdot 6\text{H}_2\text{O}$.	0.7095	1	1.2563	$124^\circ 23'$
$\text{nCa}_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 6\text{H}_2\text{O}$.				
Harmotome ,				
$\text{mBaAl}_2\text{Si}_6\text{O}_{18} \cdot 6\text{H}_2\text{O}$.	0.7031	1	1.2310	$124^\circ 50'$
$\text{nBa}_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 6\text{H}_2\text{O}$.				
WELLSITE ,				
$\text{m}(\text{Ca}, \text{Ba})\text{Al}_2\text{Si}_6\text{O}_{18} \cdot 6\text{H}_2\text{O}$.	0.7680	1	1.2450	$126^\circ 33'$
$\text{n}(\text{Ca}, \text{Ba})_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 6\text{H}_2\text{O}$.				

The first three members of the group are the most important.

STILBITE, Desmine.

Monoclinic, prismatic class. $a : b : c = 0.7624 : 1 : 1.1939$, $\beta = 129^\circ 11'$. Simple crystals are unknown, usually as tabular or penetration twins with a pseudo-orthorhombic symmetry. The common forms are the basal and clinopinacoids and the unit prism. The basal pinacoid is the twinning plane. Very commonly several twin crystals are arranged in nearly parallel, or what is sometimes called hypoparallel position, forming a sheaf-like aggregate.

Perfect clinopinacoidal cleavage. Uneven fracture. Brittle. Hardness 3 to 4. Specific gravity 2.1 to 2.2. Vitreous luster, pearly on cleavages. Transparent to translucent. Colorless to white, also brown, yellow, reddish white, or brick red. White streak.

$(\text{Ca}, \text{Na}_2)\text{Al}_2\text{Si}_6\text{O}_{18} \cdot 6\text{H}_2\text{O}$. Potassium may also be present. On heating water is liberated and the optical properties change forming *metastilbite*; when but two molecules of water are present the substance is orthorhombic, while in the anhydrous condition it is amorphous. Exfoliates and swells up, and fuses to a white glass. Decomposed by hydrochloric acid with a separation of SiO_2 .

Stilbite occurs with other zeolites in cavities in amygdaloidal basalts and related rocks, also in granites and crystalline schists, and in ore deposits. Occasionally it is deposited by hot springs, as at Olette in the Pyrenees mountains. Some localities are Arendal and Kongsberg, Norway; Bodenmais, Bavaria; Fårö Island, Sweden; Island of Disco, Greenland; Seisser Alp, Fassathal, and elsewhere, Tyrol; various places in Switzerland; Dunbastonshire, Scotland; Partridge Island and elsewhere, Nova Scotia; Bergen Hill, N. J.; Lake Superior district; Phillipstown, N. J.; Table Mountain, Colo.

Phillipsite, Christianite.

Monoclinic, prismatic class. $a : b : c = 0.7095 : 1 : 1.2563$, $\beta = 124^\circ 23'$. Crystals are never simple but always twinned parallel to the basal pinacoid. The simplest twins are pseudo-orthorhombic or pseudo-tetragonal in development. These crystals are often cruciform. Occasionally three of the crossed twins are in three rectangular directions. These structures simulate the symmetry of the cubic system, especially when the reentrant angles are filled, forming an apparent rhombic dodecahedron with characteristic striations. Occurs also in spherical, radial fibrous aggregates.

Distinct basal and clinopinacoidal cleavages. Uneven fracture. Brittle. Hardness 4 to 4.5. Specific gravity 2.2. Vitreous luster. Translucent to opaque. Colorless, white, yellowish, grayish, reddish, or bluish. White streak.

The composition of phillipsite may be expressed by the following formula: $m\text{CaAl}_2\text{Si}_6\text{O}_{16} \cdot 6\text{H}_2\text{O} + n\text{Ca}_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 6\text{H}_2\text{O}$. Calcium may be replaced in part by potassium or sodium, but never by barium. Fuses easily to a white glass. Gelatinizes with hydrochloric acid.

Occurs in cavities and fissures in basalt and related rocks. Found in Germany at Stempel near Marburg, on the Kaiserstuhl, Annerod near Giesen, and Asbach; Lauban and Sirgwitz, Bohemia; Giant's Causeway, Ireland; Mount Vesuvius; Island of Sicily.

Harmotome.

Monoclinic, prismatic class. $a : b : c = 0.7031 : 1 : 1.2310$, $\beta = 124^\circ 50'$. Crystals are similar to those of phillipsite. Crystals are generally larger than those of phillipsite. The common forms are the three pinacoids and the unit prism.

Fairly distinct basal and clinopinacoidal cleavages. Uneven fracture. Brittle. Hardness 4 to 5. Specific gravity 2.45 to 2.5. Vitreous luster. Generally translucent, sometimes milky and cloudy. White, gray, yellow, red, or brown in color. White streak.

Is an isomorphous mixture of $m\text{BaAl}_2\text{Si}_6\text{O}_{16} \cdot 6\text{H}_2\text{O}$ and $n\text{Ba}_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 6\text{H}_2\text{O}$. Contains about 20% of BaO and 1% of each of the oxides of potassium and sodium. Fuses with difficulty and without intumescence to a white glass. Sometimes phosphoresces when heated. Decomposed by hydrochloric acid, but does not gelatinize.

Occurs in amygdaloidal basalts and melaphyres, also in phonolite, trachytes, and gneisses, and further with ore deposits. Found at Andreasberg, Hartz Mountains; Bodenmais, Bavaria; Pribram, Bohemia; Zillerthal, Tyrol; Strontian, Scotland; Christiania, Norway; Rabbit Mountain, Ontario, Canada; New York City.

WELLSITE.

Monoclinic, prismatic class. $a : b : c = 0.768 : 1 : 1.245$, $\beta = 126^\circ 33'$. Small, complex twins similar to those of phillipsite and harmotome. Brittle. Hardness 4 to 4.5. Specific gravity 2.28 to 2.37. Vitreous luster. Colorless to white.

Is an isomorphous mixture $m(\text{Ca}, \text{Ba})\text{Al}_2\text{Si}_6\text{O}_{16} \cdot 6\text{H}_2\text{O}$ and $n(\text{Ca}, \text{Ba})_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 6\text{H}_2\text{O}$. Also contains potassium, sodium, and strontium. Occurs with hornblende, feldspar, corundum, and chabazite in the Buck Creek corundum mine, Clay County, N. C.

CHABAZITE GROUP

This group consists of two members which are interpreted as being isomorphous mixtures of calcium and sodium silicates containing eight molecules of water of crystallization. They crystallize in the ditrigonal scalenohedral class of the hexagonal system, cube-like rhombohedrons being rather common forms.

		$a : c$	
CHABAZITE,	$\left\{ \begin{array}{l} m\text{CaAl}_2\text{Si}_6\text{O}_{16} \cdot 8\text{H}_2\text{O} \\ n\text{Ca}_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 8\text{H}_2\text{O} \end{array} \right\}$	Hexagonal,	$1 : 1.0860$
GMELINITE,	$\left\{ \begin{array}{l} m\text{Na}_2\text{Al}_2\text{Si}_6\text{O}_{16} \cdot 8\text{H}_2\text{O} \\ n\text{Na}_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 8\text{H}_2\text{O} \end{array} \right\}$	Hexagonal,	$1 : 1.1017$

Of these minerals, chabazite is by far the more common and important.

CHABAZITE.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.0860$. Generally in cube-like rhombohedrons, the pole angle being $94^\circ 46'$, Figure 155. Crystals are sometimes more complex, Figure 156. Penetration twins having parallel c axes, the twinning plane being the basal pinacoid, are quite

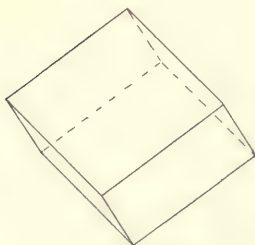


FIG. 155

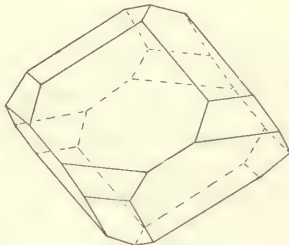


FIG. 156

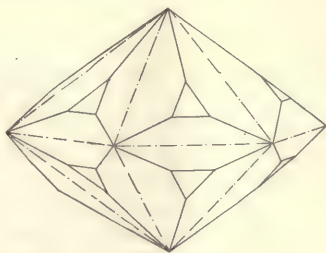


FIG. 157

common; rarer are contact twins in which the unit rhombohedron is the twinning plane. *Phacolite* is a variety occurring in twins with a lenticular, hexagonal outline, Figure 157. Occurs also in compact masses.

Fairly distinct rhombohedral cleavage. Uneven fracture. Brittle. Hardness 4 to 5. Specific gravity 2.1 to 2.2. Vitreous luster. Transparent to translucent. Colorless, white, reddish, yellowish, or brown. White streak.

An isomorphous mixture of $m\text{CaAl}_2\text{Si}_6\text{O}_{16} \cdot 8\text{H}_2\text{O}$ and $n\text{Ca}_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 8\text{H}_2\text{O}$. Contents vary considerably, SiO_2 from 44 to 50%. Also contains potassium and sodium replacing some of the calcium. Fuses with intumescence to a nearly opaque, blebby glass. Decomposed by hydrochloric acid with a separation of silica.

Associated with heulandite, stilbite, laumontite, and harmotome, it occurs frequently in cavities in basalts, phonolites, and related rocks. Also observed in granite, syenite, gneiss, mica and hornblende schists, and as a deposit of hot springs. Some localities are Oberstein and Annerod, Germany; Giant's Causeway, Ireland; Aussig, Bohemia; Fårö Island, Sweden; Greenland; Iceland: various places in Nova Scotia; Richmond, Victoria; near Baltimore, Md.; Bergen Hill, N. J.; Somerville, Mass.; Table Mountain, Colo.

GMELINITE.

Hexagonal, ditrigonal scalenohedral class. $a : c = 1 : 1.1017$. Crystals have generally an hexagonal habit, more rarely rhombohedral. Twins are not common. Distinct prismatic cleavage. Uneven fracture. Brittle. Hardness 4 to 5. Specific gravity 2.0 to 2.2. Vitreous luster. Transparent to translucent, generally translucent. Yellowish or reddish white, flesh red in color, rarely colorless.

An isomorphous mixture of $m\text{Na}_2\text{Al}_2\text{Si}_6\text{O}_{18} \cdot 8\text{H}_2\text{O}$ and $n\text{Na}_2\text{Al}_4\text{Si}_4\text{O}_{16} \cdot 8\text{H}_2\text{O}$. Also contains some calcium and potassium. Fuses easily to a white enamel. Decomposed by hydrochloric acid with a separation of silica.

Occurs in the basalt of Montecchio Maggiore, northern Italy; Antrim, Ireland; Isle of Skye, Scotland; Andreasberg, Saxony; Transylvania; Phillip Island, Victoria; Nova Scotia; Bergen Hill, N. J.

Laumontite, $\text{Ca}(\text{Al}_2\text{OH})_2(\text{Si}_2\text{O}_5)_2 \cdot 2\text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 1.1451 : 1 : 0.5906$, $\beta = 111^\circ 14'$. Occurs in long columnar crystals, and in radiating and divergent aggregates; also earthy.

Clinopinacoidal and prismatic cleavages. Hardness 3 to 4. Specific gravity 2.25 to 2.35. Uneven fracture. Not very brittle, but very friable when more or less weathered. Vitreous luster, inclining to pearly on cleavages. White, yellowish, grayish, and reddish. Uncolored.

$\text{Ca}(\text{Al}_2\text{OH})_2(\text{Si}_2\text{O}_5)_2 \cdot 2\text{H}_2\text{O}$. Loses one molecule of water in a dry atmosphere, the crystals becoming dull and cloudy, crumbling readily. The other molecule escapes only when ignited. Dehydrated varieties absorb water in a moist atmosphere. Fuses easily with intumescence to a white glass. Gelatinizes with hydrochloric acid.

Found in cavities and fissures in syenite, basalt, melaphyre, and slates, also with ore deposits. Occurs at Zillerthal, Tyrol; various places in Switzerland; Fårö Island, Sweden; Greenland; Transylvania; Port George and Peter's Point, Nova Scotia; Phippsburg, Me.; Bergen Hill, N. J.; Table Mountain, Colo.; Lake Superior copper district.

HYDRATED SILICATES CONTAINING CARBONATES, SULPHATES, AND URANATES

Several rare minerals, which are hydrated silicates containing carbonates, sulphates, and uranates are placed here. Their composition is rather complex.

THAUMASITE, $\text{CaSiO}_3 \cdot \text{CaSO}_4 \cdot \text{CaCO}_3 \cdot 15\text{H}_2\text{O}$.

Hexagonal. Usually massive, compact, or fibrous. There are traces of a cleavage. White in color. Somewhat greasy luster. Hardness about 3.5, becomes harder on exposure. Specific gravity 1.877. Infusible, but swells and colors the flame red. Occurs in Sweden and at Paterson, N. J.

URANOTILE, Uranophane, $\text{CaU}_2\text{Si}_2\text{O}_{11} \cdot 5\text{H}_2\text{O}$.

Triclinic, pinacoidal class. $a : b : c = 0.6257 : 1 : 0.5943$, $\alpha = 87^\circ 41'$, $\beta = 85^\circ 18'$, $\gamma = 96^\circ 31'$. Small, acicular crystals, often arranged radially; also fibrous and massive. Uneven to conchoidal fracture. Hardness 2.5. Specific gravity 3.8 to 3.9. Honey yellow, siskin green, or greenish black in color. May contain radium. Occurs at Kupferberg, Silesia; Wölsendorf, Bavaria; Joachimsthal, Bohemia; Villeneuve, Ottawa County, Quebec; Mitchell County, N. C.; Stone Mountain, Ga.

GUMMITE, $(\text{Pb}, \text{Ca}, \text{Ba})\text{U}_3\text{SiO}_{12} \cdot 5\text{H}_2\text{O}$.

Cryptocrystalline, apparently amorphous. Occurs compact and disseminated; sometimes reniform. Conchoidal fracture. Slightly translucent to opaque. Greasy luster. Reddish yellow, orange red, or reddish brown in color. Hardness 2.5 to 3. Specific gravity 3.9 to 4.5. Composition varies a great deal. May contain radium. Is an alteration product of uraninite. Found at Joachimsthal, Bohemia; Schneeberg and Johanngeorgenstadt, Saxony; Flat Rock mine, Mitchell County, N. C.

AMORPHOUS HYDRATED SILICATES

A number of minerals are placed here, but only one, allophane, is of sufficient importance to warrant a description.

Allophane, $\text{Al}_2\text{SiO}_5 \cdot 5\text{H}_2\text{O}$.

Amorphous. Reniform, botryoidal, stalactitic masses; also as an incrustation. Resembles opal, especially hyalite. Uneven to conchoidal fracture. Very brittle. Vitreous to resinous luster, internally bright and waxy. Usually colored green or blue by copper compounds; also colorless, yellow, brown, and red. Uncolored streak. Translucent. Infusible. Gelatinizes with hydrochloric acid. Occurs as an alteration product of aluminium silicates and is commonly associated with copper compounds. Hardness 3.

X. ORGANIC COMPOUNDS

SALTS OF ORGANIC ACIDS

Several compounds, which are salts of oxalic and mellitic acid, will be described briefly. They do not occur to any extent as minerals.

WHEWELLITE, Calcium Oxalate, $\text{CaC}_2\text{O}_4 \cdot \text{H}_2\text{O}$.

Monoclinic, prismatic class. $a : b : c = 0.8628 : 1 : 1.3677$, $\beta = 107^\circ 0'$. Tabular, prismatic, and pseudo-cubical crystals. Sometimes very large and highly modified. More than 50 forms have been recorded. Heart-shaped twins are common; orthopinacoid is the twinning plane. Basal cleavage. Specific gravity 2.225 to 2.5. Hardness 2.5. White to colorless. Vitreous to pearly luster. Occurs in coal mines in Saxony and Bohemia.

OXALITE, Humboldtine, $2\text{FeC}_2\text{O}_4 \cdot 3\text{H}_2\text{O}$.

Acicular crystals, system undetermined. Usually in fibrous or granular aggregates; also earthy, reniform, platy masses and as incrustations. Uneven to earthy fracture. Hardness 2. Specific gravity 2.13 to 2.5. Yellow color and streak. Opaque. Easily soluble in acids. Found near Bilin, Bohemia; Gross-Almeorde, Hessen, Germany; Kettle Point, Canada.

MELLITE, $\text{Al}_2\text{C}_{12}\text{O}_{12} \cdot 18\text{H}_2\text{O}$.

Tetragonal. $a : c = 1 : 0.7454$. Simple, pyramidal crystals. Massive and granular. Conchoidal fracture. Brittle. Hardness 2 to 2.5. Specific gravity 1.6. Transparent to translucent. Resinous to vitreous luster. Honey, straw, or reddish yellow in color. White streak. Soluble in nitric acid. Occurs with coal in Thuringia, Bohemia, Moravia, and Russia.

HYDROCARBONS.

Petroleum and several closely allied mixtures of various hydrocarbons will be described here.

Petroleum, Mineral Oil, Crude Oil.

A thin to thick viscous liquid with a brown, greenish brown, yellow or black color and disagreeable odor. Rarely colorless and transparent. Possesses a characteristic greenish fluorescence. Specific gravity varies from 0.6 to 0.9.

Consists generally of a mixture of various members of the paraffin series $\text{C}_n\text{H}_{2n+2}$, but may contain smaller amounts of the representatives of the naphthene C_nH_{2n} and benzene $\text{C}_n\text{H}_{2n-6}$ series. This is especially the case with Russian petroleum.

Petroleum occurs in sandstones, shales, and limestones of different geological ages. It is generally thought to be organic origin, although it

has been suggested that some petroleum may have been formed from inorganic substances. In the United States there were produced in 1908 about 180,000,000 barrels of petroleum, Oklahoma, California, Illinois, Texas, Ohio, West Virginia, Louisiana, and Pennsylvania being the largest producers. The world's production for the same year was 250,000,000 barrels, Russia, Galicia, India, Roumania, Japan, Mexico, Java, and Borneo ranking next to the United States in importance.

Petroleum, either crude or refined, finds extended use as a fuel, for lubricating and illuminating purposes, and as a source of a very large number of important chemical preparations.

Ozocerite, Ozokerite, Mineral Wax, Native Paraffin.

Compact, fibrous, or lamellar masses, sometimes streaked or spotted, consisting of microscopic, doubly refractive fibres, which are probably orthorhombic. Looks like wax or spermaceti, but is stickier. When pure is colorless to white, generally greenish to yellow brown. If bitumen is present, the color is apt to be black. Thin layers are brownish to reddish brown in transmitted light. Soft, easily indented by the finger nail. Specific gravity 0.9 to 0.97. Greasy feel.

It is essentially native paraffin. Fuses at 70° to 83°C. Becomes plastic between the fingers. Easily soluble in turpentine and benzol, with difficulty in alcohol and ether.

Occurs generally with petroleum as an impregnation in sandstones and shales, but is sometimes associated with coal. The principal localities are Boryslaw, Galicia; Slanik, Roumania; Baku, Russia; Emery and Uinta counties, Utah.

Refined ozocerite is termed *ceresin*, which is used in the manufacture of candles, ointments, pomades, hydrofluoric acid bottles, leather polishes, pencils, and sealing wax, and as an adulterant of or substitute for beeswax. *Okonite*, a mixture of a residual product obtained in the process of purification with resin, caoutchouc, and sulphur, is used extensively for insulating electrical apparatus.

Hatchettite, *urpethite*, *zietrisikite*, and *chrismatite* are very similar to ozocerite.

Asphalt, Asphaltum, Mineral Pitch.

Amorphous, either as a solid or thick liquid. Brownish to pitch black in color. Pitchy luster. When solid, it has a conchoidal fracture. Not very brittle. Hardness 1 to 2. Specific gravity 1.1 to 1.8. Has a bituminous odor. Melts at 90 to 100° and is easily inflammable. Completely or partially soluble in alcohol, ether, petroleum, or turpentine.

Asphalt is an oxidation product of petroleum and varies greatly in chemical composition. It is not confined to the rocks of any definite geological age. Occurs sometimes in large pools or lakes and in veins, more commonly, however, as impregnations in sand, shale, sandstone, and limestone. The principal localities for occurrences of the first kind are Trinidad, Barbadoes; in Venezuela, and near the Dead Sea. Utah, Oklahoma, Texas, Kentucky, Wyoming, and Arkansas have important deposits of rocks impregnated with asphalt.

Gilsonite or *uintahite* is a variety occurring near Fort Duchesne, Utah. *Elaterite* is an elastic asphalt from Derbyshire, England. *Albertite* occurs in veins at Hilsborough, Albert County, New Brunswick, and is only partially soluble in terpentine. *Grahamite* resembles albertite and is found in fissures in West Virginia.

Asphalt and allied substances are used for paving purposes, road dressing, in water-proofing metals, wood, papers, and fabrics, in electrical insulations, adulteration of rubber, briquetting of coals, and so forth.

IDRIALITE. Probably $C_{40}H_{28}O$. Occurs with cinnabar and other inorganic material. Foliated structure. Hardness 1 to 1.5. Specific gravity 1.4 to 1.6. Dull to greasy luster. Greenish, gray, or brownish black in color. Yields an indigo blue color when dissolved in hot concentrated sulphuric acid. Found at Idria.

FICHELITE, $C_{18}H_{32}$.

Monoclinic. $a : b : c = 1.415 : 1 : 1.734$, $\beta = 127^\circ$. Small, tabular crystals and aggregates. White. Pearly luster. Fuses at 46° . Occurs as an incrustation on wood in peat beds near Redwitz, Fichtelgebirge, Bavaria.

HARTITE, $C_{12}H_{20}$.

Probably monoclinic, although sometimes considered triclinic. Columnar or tabular crystals. White, gray, or yellow in color. Hardness 1 to 1.5. Specific gravity 1.05. Fuses at 74° . Very soluble in ether. Occurs with coal at Oberhart, Austria, and at Rosenthal and Oberdorf, Styria.

PYROPISSITE.

Compact and earthy. Yellow to brown in color. Shiny streak. Dull luster. Specific gravity 0.9. Easily fusible and inflammable. Occurs near Weisenfels, Saxony, and at Eisleben and Eger, Bohemia.

RESINS.

Amber, Succinite.

Amorphous. Irregular, stalactitic, and disseminated masses, varying in size from small grains to lumps weighing about 20 pounds. Large masses are, however, very rare. Conchoidal fracture. Brittle, but easily worked on the lathe. Hardness 2 to 2.5. Specific gravity 1.0 to 1.1. Clear and transparent to cloudy and translucent. Often opalescent and fluorescent. Greasy luster. Generally yellow in color, also reddish, brownish, and whitish.

Amber consists of a mixture of an amorphous insoluble substance, succinic acid, two soluble resins, and a volatile oil. Its chemical composition is generally expressed by the formula $C_{40}H_{64}O_4$. When heated, amber softens, intumesces, and yields a characteristic aromatic odor. Melts, decomposes, and evolves white fumes at 280° to 290° . (Copal, which is very similar in many respects to amber, melts at 200° to 220°). Insoluble in water. About 20 to 25% is soluble in warm alcohol, ether, chloroform, and terpentine. Often contains many inclusions, among them various insects, vegetable remains, liquids, and some minerals.

Amber is a fossil resin obtained from pre-historic conifers. It occurs principally in a glauconite sand, called *blue earth*, along the southern coast of the Baltic Sea. Eastern Prussia, especially near the east of Königsberg, has been the chief source for hundreds of years of the amber of commerce. It is also found various places along the coast of the North Sea in Courland and Livonia, Russia; Pomerania, Germany. It is reported as occurring also in Roumania: Spain; at Lemberg, Galicia; Catania, Sicily; Santa Domingo; Kreischerville, Staten Island, N. Y.; Eagle Pass and on the Terlingua Creek, Texas; near Trenton and Camden, N. J.

Amber is used in the manufacture of stems for pipes and cigar holders, small jewelry, various ornaments, varnish, and as a source of succinic acid. Chips are often pressed together and sold under the name of *ambroid*.

BURMITE is very similar to amber but does not contain succinic acid. It occurs in considerable quantities in Burma.

A comparatively large number of fossil resins are in many respects similar to amber, but differ from it principally by the entire absence or the presence of but very small amounts of succinic acid. They occur generally in coal or lignite, more rarely in sandstone, shale, or clay. The following are only a few of such substances. *Copalite* occurs in the blue clay of High Gate, near London; *Retinite* at Halle, Germany, and Bovey Tracey, Devonshire, England; *Tasmanite* in Tasmania; *Walchowite* in Moravia; *Cedarite* in Canada; and *Gedanite* in the vicinity of Königsberg, Germany.

COALS.

Although the coals are strictly speaking rocks, a brief description of the different varieties is usually given in Descriptive Mineralogy.* Coals are the accumulated remains of vegetable life, which have been more or less altered under the influence of geological processes. In some varieties the plant remains are well preserved, in others entirely obliterated. They consist principally of carbon, hydrogen, and oxygen, although small amounts of nitrogen are generally present. The percentage of carbon is usually lowest in varieties showing a distinct organic structure. The coals are found in various geological formations, from some of the oldest to those which are most recent.

Four varieties are generally differentiated: (1) *Anthracite coal*. (2) *Bituminous coal*. (3) *Lignite*, and (4) *Peat*. According to Ries these varieties have a general composition which may be expressed by the following table:—

	C	H	O	N	S	Ash	Moisture
Anthracite Coal	90.45	2.43	2.45			4.67	
Bituminous Coal	82.70	4.77	9.39	1.62	0.45	1.07	
“ “	73.80	5.79	16.58	1.52	0.41	1.90	
“ “	68.13	6.49	5.83	2.27	2.48	12.30	
Lignite	58.44	4.97	16.42	1.30			
Peat	59.47	6.52	31.51	2.51			0.22

* For detailed description, see Ries, *Economic Geology of the United States*, pp. 1 to 38.

Anthracite Coal, Hard Coal.

Contains the highest percentage of fixed carbon and the lowest of volatile hydrocarbons. Carbon varies between 80% and 96%, in the anthracites of Pennsylvania between 85% and 93%. Black to iron gray in color. Black streak. Opaque. Hardness 2 to 2.5. Specific gravity 1.3 to 1.7. Vitreous luster, often including metallic. A brilliant iridescence is sometimes observed. Amorphous and compact. Conchoidal fracture. Brittle. Does not show the organic structure. Ignites with difficulty, but gives much heat. Does not impart a color to a solution of potassium hydroxide. It occurs interbedded, principally in regions of folded strata.

Bituminous Coal, Soft Coal.

This variety ranks next to anthracite coal in the percentage of fixed carbon present, which varies from 75% to 90%. Distinct organic structure is not usually visible to the naked eye, but is easily recognized in thin sections under the microscope. Amorphous and compact, generally showing stratification; occasionally fibrous. Brittle. Brown to black in color. Brown to grayish brown streak. Vitreous, pitchy, or greasy luster. Conchoidal to cubical fracture. Hardness 2 to 2.5. Specific gravity 1.15 to 1.5. May contain as high as 30% of ash. Imparts no or only a very slight color to a solution of potassium hydroxide. Burns with a yellow, smoky flame. *Coking* coals are varieties of bituminous coal which yield coke, while *non-coking* coals do not. *Cannel* coal is a compact, coking or non-coking, bituminous coal containing a large amount of volatile constituents. It possesses a conchoidal fracture, dull lustre, ignites easily, and burns with a yellow flame.

Lignite, Brown Coal.

Usually contains from 55% to 75% of carbon. Plant remains are generally easily detected by the naked eye. Brown to black in color. Brown streak. Conchoidal fracture. Soft. Specific gravity 1.12 to 1.4. Burns easily with a long, smoky flame. The heating power is lower than for bituminous or anthracite coals. May contain much moisture, and then disintegrates easily on exposure to the air. Imparts a dark brown color to a solution of potassium hydroxide. *Jet* is a compact, resinous, coal-black variety of lignite, which takes a good polish and is used for small ornaments and cheap jewelry.

Peat.

This variety consists of accumulations of more or less decomposed plant remains. The carbon content varies between 50 and 60%. It is the first product in the formation of coal. Brownish, yellowish, or black in color. Loose and porous, often stratified. Occurs in swamps, marshes, and bogs. When dried, it serves as a fuel.

CLASSIFICATION OF MINERALS ACCORDING TO ELEMENTS

It is often desirable to know the minerals in which certain elements occur and the following tables have been arranged to meet this need. In most cases only the more important minerals are included in the classification. The minerals are given under each element in the order in which they have been described in the text. Page references to the detailed descriptions are given after the formulas.

ACTINIUM

See uraninite, page 142.

ALUMINIUM

CORUNDUM,	Hexagonal,	Al_2O_3 ,—84
Gibbsite,	Monoclinic,	$\text{Al}(\text{OH})_3$,—92
Diaspore,	Orthorhombic,	$\text{AlO}(\text{OH})$,—92
BAUXITE,	Unknown,	$\text{Al}_2\text{O}(\text{OH})_4$,—94
Fluellite,	Orthorhombic,	$\text{AlF}_3 \cdot 3\text{H}_2\text{O}$,—106
Cryolite,	Monoclinic,	Na_3AlF_6 ,—107
Alunite,	Hexagonal,	$\text{K}_2(\text{Al}_2\text{OH})_6(\text{SO}_4)_4$,—143
Aluminite,	Orthorhombic?	$\text{Al}_2(\text{OH})_4\text{SO}_4 \cdot 7\text{H}_2\text{O}$,—152
Kalinite,	Cubic,	$\text{K}_2\text{Al}_2(\text{SO}_4)_4 \cdot 24\text{H}_2\text{O}$,—154
SPINELS,	Cubic,	$\text{Mg}(\text{AlO}_2)_2$, etc.,—156
Chrysoberyl,	Orthorhombic,	$\text{Be}(\text{AlO}_2)_2$,—161
Amblygonite,	Triclinic,	$\text{Li}(\text{AlF})\text{PO}_4$,—173
Lazulite,	Monoclinic,	$\text{Mg}(\text{AlOH})_2(\text{PO}_4)_2$,—176
Variscite,	Orthorhombic,	$\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$,—179
Wavellite,	Orthorhombic,	$(\text{AlOH})_3(\text{PO}_4)_2 \cdot 5\text{H}_2\text{O}$,—180
Turquoise,	Amorphous,	$\text{Al}_2(\text{OH})_3\text{PO}_4 \cdot \text{H}_2\text{O}$,—181
STAUROLITE,	Orthorhombic,	$\text{HFeAl}_5\text{Si}_2\text{O}_{13}$,—184
ANDALUSITE,	Orthorhombic,	Al_2SiO_5 ,—187
Sillimanite,	Orthorhombic,	Al_2SiO_5 ,—188
CYANITE,	Triclinic,	Al_2SiO_5 ,—189
TOPAZ,	Orthorhombic,	$\text{Al}_2(\text{F,OH})_2\text{SiO}_4$,—190
TOURMALINE,	Hexagonal,	$\text{M}'_3\text{Al}_3(\text{B,OH})_2\text{Si}_4\text{O}_{19}$,—193
Zoisite,	Orthorhombic,	$\text{Ca}_2\text{Al}_2(\text{AlOH})(\text{SiO}_4)_3$,—199
EPIDOTE,	Monoclinic,	$\text{Ca}_2(\text{Al,Fe})_2(\text{AlOH})(\text{SiO}_4)_3$,

VESUVIANITE,	Tetragonal,	$\text{Ca}_6[\text{Al}(\text{OH}, \text{F})]\text{Al}_2(\text{SiO}_4)_5$,—202
GARNETS,	Cubic,	$\text{R}'''_2\text{Al}_2(\text{SiO}_4)_3$, etc.,—208
Prehnite,	Orthorhombic,	$\text{H}_2\text{Ca}_2\text{Al}_2(\text{SiO}_4)_3$,—213
MICAS,	Monoclinic,	$\text{H}_2\text{KAl}(\text{SiO}_4)_3$, etc.,—214
Chlorites,	Monoclinic,	$\text{H}_4\text{Mg}_2\text{Al}_2\text{SiO}_9$, etc.,—223
KAOLINITE,	Monoclinic,	$\text{H}_4\text{Al}_2\text{Si}_2\text{O}_9$,—230
Pyrophyllite,	Orthorhombic or Monoclinic,	$\text{H}_2\text{Al}_2\text{Si}_4\text{O}_{12}$,—231
Nephelite,	Hexagonal,	$(\text{Na}, \text{K})_8\text{Al}_8\text{Si}_6\text{O}_{34}$,—232
Sodalite,	Cubic,	$\text{Na}_4\text{Al}_2(\text{Al}, \text{Cl})(\text{SiO}_4)_3$,—233
Spodumene,	Monoclinic,	$\text{LiAl}(\text{SiO}_3)_2$,—247
AMPHIBOLES,	Orthorhombic and Monoclinic,	Silicates of Al, Ca, Mg, Fe—250
Leucite,	Orthorhombic and Cubic,	$\text{K}_2\text{Al}_2\text{Si}_4\text{O}_{12}$,—257
BERYL,	Hexagonal,	$\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$,—258
FELDSPARS,	Monoclinic and Triclinic,	KAlSi_3O_8 , etc.,—259
ZEOLITES,	Various systems	Hydrated silicates,—275
SCAPOLITE,	Tetragonal,	$\text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{25}$, etc.,—270
Allophane,	Amorphous,	$\text{Al}_2\text{SiO}_5 \cdot 5\text{H}_2\text{O}$,—287

ANTIMONY

Native Antimony,	Hexagonal,	Sb,—15
Allemontite,	Hexagonal,	(As, Sb),—16
STIBNITE,	Orthorhombic,	Sb_2S_3 ,—30
Breithauptite,	Hexagonal,	NiSb,—37
Ullmannite,	Cubic,	NiSbS ,—41
Dyscrasite,	Orthorhombic,	Ag_3Sb ,—46
Nagyagite,	Orthorhombic,	$\text{Au}_2\text{Sb}_2\text{Pb}_{10}\text{Te}_6\text{S}_{15}$,—54
Miargyrite,	Monoclinic,	AgSbS_2 ,—57
Zinkenite,	Orthorhombic,	PbSb_2S_4 ,—57
Plagionite,	Monoclinic,	$\text{Pb}_5\text{Sb}_8\text{S}_{17}$,—58
Jamesonite,	Orthorhombic,	$\text{Pb}_2\text{Sb}_2\text{S}_5$,—58
Boulangerite,	Orthorhombic,	$\text{Pb}_5\text{Sb}_4\text{S}_{11}$,—59
Freieslebenite,	Monoclinic,	$(\text{Pb}, \text{Ag})_2\text{Sb}_4\text{S}_{11}$,—59
Pyrargyrite,	Hexagonal,	Ag_3SbS_3 ,—59
Bournonite,	Orthorhombic,	$\text{Pb}_3\text{Cu}_2\text{Sb}_2\text{S}_6$,—60
TETRAHEDRITE,	Cubic,	$\text{M}''_4\text{Sb}_2\text{S}_7$,—61
Stephanite,	Orthorhombic,	$\text{Ag}_{10}\text{Sb}_2\text{S}_8$,—63
Polybasite,	Monoclinic,	$(\text{Ag}, \text{Cu})_9\text{SbS}_6$,—64
Senarmontite,	Cubic,	Sb_2O_3 ,—69
Valentinite,	Orthorhombic,	Sb_2O_3 ,—69
Kermesite,	Monoclinic,	$\text{Sb}_2\text{S}_2\text{O}$,—97

ARGON

See uraninite, page 142.

ARSENIC

Native Arsenic,	Hexagonal,	As,—15
Allemontite,	Hexagonal,	(As,Sb),—16
REALGAR,	Monoclinic,	AsS,—29
ORPIMENT,	Monoclinic,	As ₂ S ₃ ,—30
Niccolite,	Hexagonal,	NiAs,—37
Cobaltite,	Cubic,	CoAsS,—40
Gersdorffite,	Cubic,	NiAsS,—41
Smaltite,	Cubic,	CoAs ₂ ,—41
Chloanthite,	Cubic,	NiAs ₂ ,—42
Sperryllite,	Cubic,	PtAs ₂ ,—42
ARSENOPYRITE,	Orthorhombic,	FeAsS,—43
Löllingite,	Orthorhombic,	FeAs ₂ ,—44
Glaucodote,	Orthorhombic,	(Co,Fe)AsS,—44
Safflorite,	Orthorhombic,	CoAs ₂ ,—44
Rammelsbergite,	Orthorhombic,	NiAs ₂ ,—45
Skutterudite,	Cubic,	CoAs ₃ ,—45
Whitneyite,	Unknown,	Cu ₀ As,—45
Algodonite,	Unknown,	Cu ₆ As,—45
Domeykite,	Orthorhombic,	Cu ₃ As,—46
Lorandite,	Monoclinic,	TlAsS ₂ ,—57
Proustite,	Hexagonal,	Ag ₃ AsS ₃ ,—59
TETRAHEDRITE,	Cubic,	M'' ₄ As ₂ S ₇ ,—61
Jordanite,	Monoclinic,	Pb ₄ As ₂ S ₇ ,—62
Enargite,	Orthorhombic,	Cu ₃ AsS ₄ ,—64
Arsenolite,	Cubic,	As ₂ O ₃ ,—69
Mimetite,	Hexagonal,	Pb ₅ Cl(AsO ₄) ₃ ,—173
Adamite,	Orthorhombic,	Zn(Zn.OH)AsO ₄ ,—175
Olivenite,	Orthorhombic,	Cu(Cu.OH)AsO ₄ ,—175
Erythrite,	Monoclinic,	Co ₃ (AsO ₄) ₃ .8H ₂ O,—178
Annabergerite,	Monoclinic,	Ni ₃ (AsO ₄) ₃ .8H ₂ O,—179
Scorodite,	Orthorhombic,	FeAsO ₄ .2H ₂ O,—179
Pharmacolite,	Monoclinic,	CaHAsO ₄ .2H ₂ O,—180
Pharmacosiderite,	Cubic,	Fe(Fe.OH) ₃ (AsO ₄) ₃ .6H ₂ O,—180

BARIUM

Bromlite,	Orthorhombic,	(Ca,Ba)CO ₃ ,—121
WITHERITE,	Orthorhombic,	BaCO ₃ ,—122
Barytocalcite,	Monoclinic,	BaCO ₃ .CaCO ₃ ,—123
Bartocelestite,	Orthorhombic,	(Sr,Ba)SO ₄ ,—135
BARITE,	Orthorhombic,	BaSO ₄ ,—135
Barylite,	Orthorhombic?	Ba ₄ Al ₄ Si ₇ O ₂₄ ,—235
Hyalophane,	Monoclinic,	KAlSi ₃ O ₈ +BaAl ₂ Si ₂ O ₈ ,—263
Celsian,	Triclinic,	BaAl ₂ Si ₂ O ₈ ,—269
Benitoite,	Hexagonal,	BaTiSi ₃ O ₉ ,—274
Edingtonite,	Orthorhombic and Monoclinic	BaAl(Al.2OH)(SiO ₃) ₃ .2H ₂ O,

Brewsterite,	Monoclinic,	$H_4(Sr,Ba)Al_2(SiO_3)_6 \cdot 3H_2O$,—282
Harmotome,	Monoclinic,	$BaAl_2Si_6O_{16} \cdot 6H_2O$, etc.,—284
Wellsite,	Monoclinic,	$(Ca,Ba)Al_2Si_6O_{16} \cdot 6H_2O$, etc.,—284

See also psilomelane, 129.

BERYLLIUM

Chrysoberyl,	Orthorhombic,	$Be(AlO_2)_2$,—161
Beryllonite,	Orthorhombic,	$NaBePO_4$,—165
Herderite,	Monoclinic,	$Ca(Be.OH)PO_4$,—175
Euclase,	Monoclinic,	$Be(Al.OH)SiO_4$,—192
Gadolinite,	Monoclinic,	$Fe[Be(Y.O)SiO_4]_2$,—193
Helvite,	Cubic,	$(Mn,Be,Fe)_7S(SiO_4)_3$,—198
Danalite,	Cubic,	$(Fe,Zn,Be,Mn)_7S(SiO_4)_3$,—198
Phenacite,	Hexagonal,	Be_2SiO_4 ,—205
BERYL,	Hexagonal,	$Be_3Al_2(SiO_3)_6$,—257
Eudidymite,	Monoclinic,	$HNaBeSi_3O_8$,—271
Epididymite,	Orthorhombic,	$HNaBeSi_3O_8$,—271

See also tscheffkinite, 273, and steenstrupine, 273.

BISMUTH

Native Bismuth,	Hexagonal,	Bi,—16
Bismuthinite,	Orthorhombic,	Bi_2S_3 ,—31
Guanajuatite,	Orthorhombic,	$Bi_2(Se,S)_3$,—31
Tetradymite,	Hexagonal,	Bi_2Te_2S ,—31
Emplectite,	Orthorhombic,	$Cu_2Bi_2S_4$,—57
Cosalite,	Orthorhombic,	$Pb_2Bi_2S_5$,—58
Aikinite,	Orthorhombic,	$Pb_2Cu_2Bi_2S_6$,—61
Bismite,	Orthorhombic,	Bi_2O_3 ,—70
Bismutite,	Amorphous,	$Bi_2CO_5 \cdot H_2O$,—125
Eulytite,	Cubic,	$Bi_4(SiO_4)_3$,—207
Agricolite,	Monoclinic,	$Bi_4(SiO_4)_3$,—208

BORON

Sassolite,	Triclinic,	$B(OH)_3$,—91
Sussexite,	Unknown,	$[(Mn,Mg)OH]BO_2$,—162
Boracite,	Orthorhombic and Cubic,	$Mg_7Cl_2B_{16}O_{30}$,—162
BORAX,	Monoclinic,	$Na_2B_4O_7 \cdot 10H_2O$,—163
Ulexite,	Monoclinic,	$NaCaB_5O_9 \cdot 6H_2O$,—163
Pandermite,	Monoclinic,	$Ca_2B_6O_{11} \cdot 3H_2O$,—164
Colemanite,	Monoclinic,	$Ca_2B_6O_{11} \cdot 5H_2O$,—164
Sulfoborite,	Orthorhombic,	$4MgHBO_3 \cdot 2MgSO_4 \cdot 7H_2O$,—164
Dumortierite,	Orthorhombic,	$HBAI_8Si_3O_{20}$,—185

CLASSIFICATION ACCORDING TO ELEMENTS

Datolite,	Monoclinic,	$\text{Ca}(\text{B.OH})\text{SiO}_4$,—192
Homilite,	Monoclinic,	$\text{Fe}[\text{Ca}(\text{B.O})\text{SiO}_4]_2$,—193
TOURMALINE,	Hexagonal,	$\text{M}'_3\text{Al}_3(\text{B.OH})_2\text{Si}_4\text{O}_{19}$,—193
Danburite,	Orthorhombic,	$\text{CaB}_2(\text{SiO}_4)_2$,—207
Axinite,	Triclinic,	$\text{R}''_7\text{R}'''_4\text{B}_2(\text{SiO}_4)_8$,—213

BROMINE

Only a few minerals contain bromine.

Embolite,	Cubic,	$\text{Ag}(\text{Cl},\text{Br})$,—102
Bromyrite,	Cubic,	AgBr ,—102
Iodobromite,	Cubic,	$\text{Ag}(\text{Cl},\text{Br},\text{I})$,—102

CADMIUM

There are only two minerals containing cadmium in sufficiently large quantities to find expression in the formulas.

Greenockite,	Hexagonal,	CdS ,—35
Oxide of Cadmium,	Cubic,	CdO ,—83

Not infrequently present in small quantities in sphalerite, 33, wurtzite, 35, and smithsonite, 117.

CAESIUM

There is only one caesium mineral.

Pollucite,	Cubic,	$\text{H}_2\text{Cs}_4\text{Al}_4(\text{SiO}_8)_9$
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Caesium is often present in small quantities in lepidolite, 219, and beryl, 257.

CALCIUM

Oldhamite,	Cubic,	CaS ,—33
Hydrophilite,	Cubic,	CaCl_2 ,—103
FLUORITE,	Cubic,	CaF_2 ,—103
Tachydrite,	Hexagonal,	$2\text{MgCl}_2 \cdot \text{CaCl}_2 \cdot 12\text{H}_2\text{O}$,—107
CALCITE,	Hexagonal,	CaCO_3 ,—111
DOLOMITE,	Hexagonal,	$\text{CaMg}(\text{CO}_3)_2$,—115
Ankerite,	Hexagonal,	$(\text{Ca},\text{Mg},\text{Fe})\text{CO}_3$,—116
Manganocalcite,	Hexagonal,	$(\text{Mn},\text{Ca})\text{CO}_3$,—118
ARAGONITE,	Orthorhombic,	CaCO_3 ,—119
Bromlite,	Orthorhombic,	$(\text{Ca},\text{Ba})\text{CO}_3$,—121
Tarnowitzite,	Orthorhombic,	$(\text{Ca},\text{Pb})\text{CO}_3$,—122
Bartyocalcite,	Monoclinic,	$\text{BaCO}_3 \cdot \text{CaCO}_3$,—123
Pirssonite,	Orthorhombic,	$\text{Na}_2\text{CO}_3 \cdot \text{CaCO}_3 \cdot 2\text{H}_2\text{O}$,—127
Gay-Lussite,	Monoclinic,	$\text{Na}_2\text{CO}_3 \cdot \text{CaCO}_3 \cdot 5\text{H}_2\text{O}$,—127
Glauberite,	Monoclinic,	$\text{Na}_2\text{SO}_4 \cdot \text{CaSO}_4$,—132

ANHYDRITE ,	Orthorhombic,	CaSO_4 ,—133
Powellite,	Tetragonal,	CaMoO_4 ,—139
Scheelite ,	Tetragonal,	CaWO_4 ,—139
GYPSUM ,	Monoclinic,	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$,—146
Ulexite ,	Monoclinic,	$\text{NaCaB}_5\text{O}_{10} \cdot 6\text{H}_2\text{O}$,—163
Pandermite,	Monoclinic,	$\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 3\text{H}_2\text{O}$,—164
COLEMANITE ,	Monoclinic,	$\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 5\text{H}_2\text{O}$,—164
APATITE ,	Hexagonal,	$\text{Ca}_5\text{F}(\text{PO}_4)_3$,—170
Autunite,	Orthorhombic,	$\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$,—182
Clinohedrite,	Monoclinic,	$(\text{Zn.OH})(\text{Ca.OH})\text{SiO}_3$,—187
Datolite ,	Monoclinic,	$\text{Ca}(\text{B.OH})\text{SiO}_4$,—192
Homilite,	Monoclinic,	$\text{Fe}[\text{Ca}(\text{B.O})\text{SiO}_4]_2$,—193
Lawsonite,	Orthorhombic,	$\text{Ca}(\text{Al}_2\text{OH})_2(\text{SiO}_3)_2$,—196
Ilvaite ,	Orthorhombic,	$\text{CaFe}_2(\text{Fe.OH})(\text{SiO}_4)_2$,—196
Zoisite ,	Orthorhombic,	$\text{Ca}_2\text{Al}_2(\text{Al.OH})(\text{SiO}_4)_3$,—199
Clinozoisite,	Monoclinic,	$\text{Ca}_2\text{Al}_2(\text{Al.OH})(\text{SiO}_4)_3$,—199
EPIDOTE ,	Monoclinic,	$\text{Ca}_2(\text{Al,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$, —200
Piemontite,	Monoclinic,	$\text{Ca}_2(\text{Mn,Al})_2(\text{Al.OH})(\text{SiO}_4)_3$, —201
Orthite ,	Monoclinic,	$\text{Ca}_2(\text{Al,Ce,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$, —201
VESUVIANITE ,	Tetragonal,	$\text{Ca}_6[\text{Al}(\text{OH,F})]\text{Al}_2(\text{SiO}_4)_5$,—202
Monticellite,	Orthorhombic,	CaMgSiO_4 ,—203
GARNET ,	Cubic,	$\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$, etc.,—208
Prehnite ,	Orthorhombic,	$\text{H}_2\text{Ca}_2\text{Al}_2(\text{SiO}_4)_3$,—213
Hardystonite,	Tetragonal,	$\text{Ca}_2\text{ZnSi}_2\text{O}_7$,—235
Perovskite ,	Pseudo-cubic,	CaTiO_3 ,—238
PYROXENES ,	Orthorhombic, Monoclinic, and Triclinic,	$\text{CaMg}(\text{SiO}_3)_2$, etc.,—240
AMPHIBOLES ,	Orthorhombic, Monoclinic, and Triclinic,	$\text{CaMg}_3(\text{SiO}_3)_4$, etc.,—251
ANORTHITE and PLAGIOCLASES ,	Triclinic,	$\text{CaAl}_2\text{Si}_2\text{O}_8$, etc.,—268
SCAPOLITE ,	Tetragonal,	$\text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{25}$, etc.,—270
TITANITE ,	Monoclinic,	CaTiSiO_5 ,—271
ZEOLITES ,	Various systems,	Hydrated silicates,—275
Whewellite,	Monoclinic,	$\text{CaC}_2\text{O}_4 \cdot \text{H}_2\text{O}$,—288

CARBON

DIAMOND ,	Cubic,	C,—3
GRAPHITE ,	Hexagonal,	C,—11
Schungite,	Amorphous,	C,—12

Carbon is also an essential constituent of the carbonates, pages 110 to 128. and of the organic substances described on pages 288 to 292. See the lists of the various elements.

CERIUM

Tysonite,	Hexagonal,	$(\text{Ce}, \text{La}, \text{Di}) \text{F}_3$,—105
Monazite,	Monoclinic,	$(\text{Ce}, \text{La}, \text{Di}) \text{PO}_4$,—167
Orthite,	Monoclinic,	$\text{Ca}_2(\text{Al}, \text{Ce}, \text{Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$, —201
Cerite,	Orthorhombic,	$\text{H}_6(\text{Ca}, \text{Fe})_2\text{Ce}_6\text{Si}_6\text{O}_{28}$,—202

See also thorite, 80, uraninite, 142, gadolinite, 193, tscheffkinite, 273, steenstrupine, 273, polymignite, 274, aeschynite, 274, and euxenite, 274.

CHLORINE

Chlorine is an essential constituent of the chlorides, pages 98 to 108. Also consult the lists of the various elements. It is present in small amounts in sulphohalite, 145, hanksite, 145, kainite, 154, apatite and related minerals, 170 to 173, davyne, 233, sodalite, 233, and lazurite, 234.

CHROMIUM

Crocoite,	Monoclinic,	PbCrO_4 ,—138
Chromite,	Cubic,	$(\text{Fe}, \text{Cr})[(\text{Cr}, \text{Fe})\text{O}_2]_2$,—158
Uvarovite,	Cubic,	$\text{Ca}_3(\text{Al}, \text{Cr})_2(\text{SiO}_4)_3$,—211

COBALT

Cobaltite,	Cubic,	CoAsS_2 ,—40
Smaltite,	Cubic,	CoAs_2 ,—41
Glaucodote,	Orthorhombic,	$(\text{Co}, \text{Fe})\text{AsS}$,—44
Safflorite,	Orthorhombic,	CoAs_2 ,—44
Skutterudite,	Cubic,	CoAs_3 ,—45
Linnaeite,	Cubic,	$(\text{Ni}, \text{Co})_3\text{S}_4$,—56
Winklerite,	Unknown,	$(\text{Co}, \text{Ni})_2\text{O}(\text{OH})_4$,—94
Sphaerocobaltite,	Hexagonal,	CoCO_3 ,—119
Bieberite,	Monoclinic,	$\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$,—151
Erythrite,	Monoclinic,	$\text{Co}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$,—178
Köttigite,	Monoclinic,	$(\text{Zn}, \text{Co})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$,—179

COLUMBIUM

See niobium, page 309.

COPPER

NATIVE COPPER,	Cubic,	Cu ,—21
Whitneyite,	Unknown,	Cu_9As ,—45
Algodonite,	Unknown,	Cu_8As ,—45

Domeykite,	Orthorhombic,	Cu_3As ,—46
CHALCOCITE ,	Orthorhombic,	Cu_2S ,—49
Stromeyerite ,	Orthorhombic,	$(\text{Cu},\text{Ag})_2\text{S}$,—50
Covellite ,	Hexagonal,	CuS ,—51
Barnhardtite,	Unknown,	$\text{Cu}_4\text{Fe}_2\text{S}_5$,—54
BORNITE ,	Cubic,	Cu_5FeS_3 ,—55
CHALCOPYRITE ,	Tetragonal,	CuFeS_2 ,—55
Emplectite,	Orthorhombic,	$\text{Cu}_2\text{Bi}_2\text{S}_4$,—57
Bournonite ,	Orthorhombic,	$\text{Pb}_2\text{Cu}_2\text{Sb}_2\text{S}_6$,—60
Aikinite,	Orthorhombic,	$\text{Pb}_2\text{Cu}_2\text{Bi}_2\text{S}_6$,—61
TETRAHEDRITE ,	Cubic,	$\text{M}''_4\text{R}'''_2\text{S}_{77}$,—61
Pearceite,	Monoclinic,	$(\text{Ag},\text{Cu})_9\text{AsS}_6$,—63
Polybasite ,	Monoclinic,	$(\text{Ag},\text{Cu})_9\text{SbS}_6$,—64
Enargite ,	Orthorhombic,	Cu_3AsS_4 ,—64
Stannite ,	Tetragonal,	$\text{Cu}_2\text{FeSnS}_4$,—65
CUPRITE ,	Cubic,	Cu_2O ,—88
Melaconite,	Monoclinic,	CuO ,—89
(Tenorite)		
Nantokite,	Cubic,	Cu_2Cl_2 ,—105
Marshite,	Cubic,	Cu_2I_2 ,—105
Atacamite ,	Orthorhombic,	$\text{Cu}(\text{OH})\text{Cl}\cdot\text{Ca}(\text{OH})_2$,—108
MALACHITE ,	Monoclinic,	$\text{CuCO}_3\cdot\text{Cu}(\text{OH})_2$,—124
AZURITE ,	Monoclinic,	$2\text{CuCO}_3\cdot\text{Cu}(\text{OH})_2$,—124
Aurichalcite,	Monoclinic,	$2(\text{Zn},\text{Cu})\text{CO}_3\cdot 3(\text{Zn},\text{Cu})(\text{OH})_2$,—125
Linarite,	Monoclinic,	$(\text{Pb},\text{Cu})\text{SO}_4(\text{Pb},\text{Cu})(\text{OH})_2$,—144
Stelznerite,	Orthorhombic,	$\text{CuSO}_4\cdot 2\text{Cu}(\text{OH})_2$,—144
Brochantite ,	Orthorhombic,	$\text{CuSO}_4\cdot 3\text{Cu}(\text{OH})_2$,—144
Cupromagnesite,	Monoclinic,	$(\text{Cu},\text{Mg})\text{SO}_4\cdot 7\text{H}_2\text{O}$,—151
Chalcanthite,	Triclinic,	$\text{CuSO}_4\cdot 5\text{H}_2\text{O}$,—151
Libethenite,	Orthorhombic,	$\text{Cu}(\text{Cu.OH})\text{PO}_4$,—175
Olivenite,	Orthorhombic,	$\text{Cu}(\text{Cu.OH})\text{AsO}_4$,—175
Clinoclasite,	Monoclinic,	$(\text{Cu.OH})_3\text{AsO}_4$,—176
Euchroite,	Orthorhombic,	$\text{Cu}(\text{Cu.OH})\text{AsO}_4\cdot 3\text{H}_2\text{O}$,—180
Chalcophyllite,	Hexagonal,	$(\text{Cu.OH})_8\text{AsO}_4\cdot \text{Cu}(\text{OH})_2\cdot 3\frac{1}{2}\text{H}_2\text{O}$,—180
Torbernite,	Tetragonal,	$\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2\cdot 8\text{H}_2\text{O}$,—182
Zeunerite,	Tetragonal,	$\text{Cu}(\text{UO}_2)_2(\text{AsO}_4)_2\cdot 8\text{H}_2\text{O}$,—182
Dioptase ,	Hexagonal,	H_2CuSiO_4 ,—211
Chrysocolla ,	Amorphous,	$\text{H}_2\text{CuSiO}_4\cdot \text{H}_2\text{O}$,—212

DIDYMIUM

See the cerium, thorium, and yttrium minerals, pages 299, 315, and 317.

ERBIUM

Same as for cerium.

FLUORINE

FLUORITE ,	Cubic,	CaF_2 ,—103
Sellaite,	Tetragonal,	MgF_2 ,—104
Tysonite,	Hexagonal,	$(\text{Ce}, \text{La}, \text{Di}) \text{F}_3$,—105
CRYOLITE ,	Monoclinic,	Na_3AlF_6 ,—107
Pachnolite,	Monoclinic,	$\text{AlF}_3 \cdot \text{NaCaF}_3 \cdot \text{H}_2\text{O}$,—108
Thomsenolite,	Monoclinic,	$\text{AlF}_3 \cdot \text{NaCaF}_3 \cdot \text{H}_2\text{O}$,—108
Sulphohalite,	Cubic,	$3\text{Na}_2\text{SO}_4 \cdot \text{NaCl} \cdot \text{NaF}$,—145
APATITE ,	Hexagonal,	$\text{Ca}_5\text{F}(\text{PO}_4)_3$,—170
Amblygonite ,	Triclinic,	$\text{Li}(\text{AlF})\text{PO}_4$,—173
Tilasite,	Monoclinic,	$\text{Ca}(\text{Mg}, \text{F})\text{AsO}_4$,—174
Wagnerite,	Monoclinic,	$\text{Mg}(\text{Mg}, \text{F})\text{PO}_4$,—175
Triplite,	Monoclinic,	$\text{Fe}(\text{Fe}, \text{F})\text{PO}_4$,—176
TOPAZ ,	Orthorhombic,	$\text{Al}_2(\text{F}, \text{OH})_2\text{SiO}_4$,—190
Chondrodite ,	Monoclinic,	$[\text{Mg}(\text{F}, \text{OH})]_2\text{Mg}_3(\text{SiO}_4)_2$,—197
Humite,	Orthorhombic,	$[\text{Mg}(\text{F}, \text{OH})]_2\text{Mg}_5(\text{SiO}_4)_3$,—197
Clinohumite,	Monoclinic,	$[\text{Mg}(\text{F}, \text{OH})]_2\text{Mg}_7(\text{SiO}_4)_4$,—198
VESUVIANITE ,	Tetragonal,	$\text{Ca}_6[\text{Al}(\text{OH}, \text{F})]\text{Al}_2(\text{SiO}_4)_5$,—202
Lepidolite ,	Monoclinic,	$(\text{Li}, \text{K})_2(\text{F}, \text{OH})_2\text{Al}_2\text{Si}_3\text{O}_{10}$,—219
Zinnwaldite,	Monoclinic,	$(\text{Li}, \text{K})_3(\text{F}, \text{OH})_2\text{Al}_3\text{FeSi}_5\text{O}_{10}$,—220

See also tourmaline, page 193.

GALLIUM

See sphalerite, page 34.

GERMANIUM

Only two minerals contain germanium.

Canfieldite,	Cubic,	$\text{Ag}_8(\text{Sn}, \text{Ge})\text{S}_6$,—66
Argyrodite,	Cubic,	Ag_8GeS_6 ,—66

GLUCINIUM

See beryllium, page 296.

GOLD

NATIVE GOLD ,	Cubic,	Au ,—25
Gold Amalgam,	Cubic,	$(\text{Au}, \text{Hg}, \text{Ag})$,—28
Petzite,	Orthorhombic,	$(\text{Ag}, \text{Au})_2\text{Te}$,—50
Sylvanite ,	Monoclinic,	$(\text{Au}, \text{Ag})\text{Te}_2$,—53
Calaverite ,	Monoclinic,	AuTe_2 ,—54
Krennerite,	Orthorhombic,	$(\text{Au}, \text{Ag})\text{Te}_2$,—54
Nagyargite,	Orthorhombic,	$\text{Au}_2\text{Sb}_2\text{Pb}_{10}\text{Te}_6\text{S}_{15}$,—54

HELIUM

See uraninite, page 142.

HYDROGEN

Hydrogen, combined with oxygen either as water or the hydroxyl, is present in many minerals, especially the oxides, hydroxides, and those containing water of crystallization. It is also present in the hydrocarbons. See the lists of the various elements.

INDIUM

See sphalerite, page 34.

IODINE

Iodobromite,	Cubic,	$\text{Ag}(\text{Cl}, \text{Br}, \text{I}), -102$
Miersite,	Cubic,	$\text{AgI}, -102$
Iodyrite,	Hexagonal,	$\text{AgI}, -102$
Marshite,	Cubic,	$\text{Cu}_2\text{I}_2, -105$
Lautarite,	Monoclinic,	$\text{Ca}(\text{IO}_3)_2, -109$

IRIDIUM

Platiniridium,	Cubic,	$(\text{Pt}, \text{Ir}), -17$
Native Iridium,	Cubic,	$\text{Ir}, -18$
Iridosmium,	Hexagonal,	$(\text{Os}, \text{Ir}), -18$
Osmiridium,	Hexagonal,	$(\text{Ir}, \text{Os}), -19$

IRON

Native Iron,	Cubic,	$\text{Fe}, -19$
Troilite,	Cubic,	$\text{FeS}, -35$
Pentlandite,	Cubic,	$(\text{Fe}, \text{Ni})\text{S}, -35$
PYRRHOTITE,	Hexagonal,	$\text{FeS}, -36$
PYRITE,	Cubic,	$\text{FeS}_2, -39$
MARCASITE,	Orthorhombic,	$\text{FeS}_2, -42$
ARSENOPYRITE,	Orthorhombic,	$\text{FeAsS}, -43$
Löllingite,	Orthorhombic,	$\text{FeAs}_2, -44$
Glaucodote,	Orthorhombic,	$(\text{Co}, \text{Fe})\text{AsS}, -44$
BORNITE,	Cubic,	$\text{Cu}_3\text{FeS}_3, -55$
CHALCOPYRITE,	Tetragonal,	$\text{CuFeS}_2, -55$
TETRAHEDRITE,	Cubic,	$\text{M}''_4\text{R}'''_2\text{S}_7, -61$
Stannite,	Tetragonal,	$\text{Cu}_2\text{FeSnS}_4, -65$
HEMATITE,	Hexagonal,	$\text{Fe}_2\text{O}_3, -86$

GOETHITE ,	Orthorhombic,	FeO.OH ,—93
Xanthosiderite,	Unknown,	$\text{Fe}_2\text{O}(\text{OH})_4$,—94
LIMONITE ,	Orthorhombic?	$\text{Fe}_4\text{O}_3(\text{OH})_8$,—95
Molysite,	Hexagonal,	FeCl_3 ,—105
Douglasite,	Unknown,	$\text{FeCl}_{2.2}\text{KCl.2H}_2\text{O}$,—107
Ankerite,	Hexagonal,	$(\text{Ca,Mg,Fe})\text{CO}_3$,—116
Breunnerite,	Hexagonal,	$(\text{Mg,Fe})\text{CO}_3$,—117
Monheimite,	Hexagonal,	$(\text{Zn,Fe})\text{CO}_3$,—118
Manganosiderite,	Hexagonal,	$(\text{Mn,Fe})\text{CO}_3$,—118
Oligonite,	Hexagonal,	$(\text{Fe,Mn})\text{CO}_3$,—118
SIDERITE ,	Hexagonal,	FeCO_3 ,—118
Bixbyite,	Cubic,	FeMnO_3 ,—128
WOLFRAMITE ,	Monoclinic,	$(\text{Fe,Mn})\text{WO}_4$,—141
Ferberite,	Monoclinic,	FeWO_4 ,—142
Jarosite,	Hexagonal,	$\text{K}_2(\text{Fe.2OH})_6(\text{SO}_4)_4$,—144
Natrojarosite,	Hexagonal,	$\text{Na}_2(\text{Fe.2OH})_6(\text{SO}_4)_4$,—144
Plumbojarosite,	Hexagonal,	$\text{Pb}(\text{Fe.2OH})_6(\text{SO}_4)_4$,—145
Melanterite ,	Monoclinic,	$\text{FeSO}_4.7\text{H}_2\text{O}$,—151
Pisanite,	Monoclinic,	$(\text{Fe,Cu})\text{SO}_4.7\text{H}_2\text{O}$,—151
Coquimbite,	Hexagonal,	$\text{Fe}_2(\text{SO}_4)_3.9\text{H}_2\text{O}$,—152
Copiapite ,	Monoclinic,	$\text{Fe}_2(\text{Fe.OH})_2(\text{SO}_4)_5.18\text{H}_2\text{O}$,—152
Halotrichite,	Cubic,	$\text{FeAl}_3(\text{SO}_4)_4.2\text{H}_2\text{O}$,—154
Spinel s,	Cubic,	$(\text{Fe,Mg})(\text{AlO}_2)_2$, etc.,—155
FRANKLINITE ,	Cubic,	$(\text{Fe,Mn,Zn})(\text{FeO}_2)_2$,—158
CHROMITE ,	Cubic,	$(\text{Fe,Cr})[(\text{Cr,Fe})\text{O}_2]_2$,—158
Jacobsite,	Cubic,	$\text{Mn}[(\text{Fe,Mn})\text{O}_2]_2$,—159
Magnesioferrite,	Cubic,	$\text{Mg}(\text{FeO}_2)_2$,—159
MAGNETITE ,	Cubic,	$\text{Fe}(\text{FeO}_2)_3$,—159
Triphylite,	Orthorhombic,	$\text{Li}(\text{Fe,Mn})\text{PO}_4$,—165
Tantalite ,	Orthorhombic,	$(\text{Fe,Mn})[(\text{Ta,Nb})\text{O}_3]_2$,—168
COLUMBITE ,	Orthorhombic,	$(\text{Fe,Mn})[(\text{Nb,Ta})\text{O}_3]_2$,—169
Triplite,	Monoclinic?	$\text{Fe}(\text{Fe,F})\text{PO}_4$,—176
Dufrenite,	Orthorhombic,	$\text{Fe}_2(\text{OH})_3\text{PO}_4$,—176
Vivianite ,	Monoclinic,	$\text{Fe}_3(\text{PO}_4)_2.8\text{H}_2\text{O}$,—178
Symplectite,	Monoclinic,	$\text{Fe}_3(\text{AsO}_4)_2.8\text{H}_2\text{O}$,—178
Strengite,	Orthorhombic,	$\text{FePO}_4.2\text{H}_2\text{O}$,—179
Scorodite ,	Orthorhombic,	$\text{FeAsO}_4.2\text{H}_2\text{O}$,—179
Pharmacosiderite,	Cubic,	$\text{Fe}(\text{Fe.OH})_3(\text{AsO}_4)_3.6\text{H}_2\text{O}$,—180
Childrenite,	Orthorhombic,	$(\text{Fe,Mn})\text{Al}(\text{OH})_2\text{PO}_4.\text{H}_2\text{O}$,—181
STAUROLITE ,	Orthorhombic,	$\text{HFeAl}_3\text{Si}_3\text{O}_{13}$,—184
Homilite,	Monoclinic,	$\text{Fe}[\text{Ca}(\text{B.O})\text{SiO}_4]_2$,—193
Gadolinite ,	Monoclinic,	$\text{Fe}[\text{Be}(\text{Y.O})\text{SiO}_4]_2$,—193
Ilvaite ,	Orthorhombic,	$\text{CaFe}_2(\text{Fe.OH})(\text{SiO}_4)_2$,—196
Helvite,	Cubic,	$(\text{Mn,Bc,Fe})_7\text{S}(\text{SiO}_4)_3$,—198
Danalite,	Cubic,	$(\text{Fe,Zn,Bc,Mn})_7\text{S}(\text{SiO}_4)_3$,—198
EPIDOTE ,	Monoclinic,	$\text{Ca}_2(\text{Al,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$,—200
Orthite ,	Monoclinic,	$\text{Ca}_2(\text{Al,Ce,Fe})_2(\text{Al.OH})(\text{SiO}_4)_3$,—201

OLIVINE,	Orthorhombic,	$(\text{Mg,Fe})_2\text{SiO}_4$,—204
Hortonolite,	Orthorhombic,	$(\text{Fe,Mg,Mn})_2(\text{SiO}_4)$,—205
Fayalite,	Orthorhombic,	Fe_2SiO_4 ,—205
Pseudobrookite,	Orthorhombic,	$\text{Fe}_4(\text{TiO}_4)_3$,—207
GARNET,	Cubic,	$\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3$, etc.,—208
BIOTITE,	Monoclinic,	$(\text{K,H})_2(\text{Mg,Fe})_2(\text{Al,Fe})_2(\text{SiO}_4)_3$, —215
Chloritoid,	Monoclinic,	$\text{H}_2\text{FeAl}_2\text{SiO}_7$,—222
Nontzonite,	Monoclinic,	$\text{H}_4\text{Fe}_2\text{Si}_2\text{O}_9$,—231
Iolite,	Orthorhombic,	$(\text{Mg,Fe})_4\text{Al}_8(\text{OH})_2(\text{Si}_2\text{O}_7)_5$,—236
Astrophyllite,	Orthorhombic,	$(\text{K,Na,H})_4(\text{Fe,Mn})_4(\text{Si,Ti})_5\text{O}_{16}$, —237
Ilmenite,	Hexagonal,	FeTiO_3 ,—239
PYROXENES,	Orthorhombic, Monoclinic, and Triclinic,	$(\text{Mg,Fe})_2(\text{SiO}_3)_2$, etc.,—240
AMPHIBOLES,	Orthorhombic, Monoclinic, and Triclinic,	$\text{Ca}(\text{Mg,Fe})_3(\text{SiO}_3)_4$, etc.,—250
Neptunite,	Monoclinic,	$(\text{Na,K})_2(\text{Fe,Mn})(\text{Si,Ti})_5\text{O}_{12}$, —275
Oxalite,	Unknown,	$2\text{FeC}_2\text{O}_4 \cdot 3\text{H}_2\text{O}$,—288

LATHANUM

See the cerium, thorium, and yttrium minerals pages 299, 315, and 317.

LEAD

Native Lead,	Cubic,	Pb,—20
GALENA,	Cubic,	PbS,—47
Clausthalite,	Cubic,	PbSe,—48
Altaite,	Cubic,	PbTe,—48
Naumannite,	Cubic,	$(\text{Ag}_2,\text{Pb})\text{Se}$,—49
Nagyagite,	Orthorhombic,	$\text{Au}_2\text{Sb}_2\text{Pb}_{10}\text{Te}_6\text{S}_{15}$,—54
Scleroclase,	Orthorhombic,	PbAs_2S_4 ,—57
Zinkenite,	Orthorhombic,	PbSb_2S_4 ,—57
Dufrenoyite,	Monoclinic,	$\text{Pb}_2\text{As}_2\text{S}_5$,—58
Jamesonite,	Orthorhombic,	$\text{Pb}_2\text{Sb}_2\text{S}_5$,—58
Cosalite,	Orthorhombic,	$\text{Pb}_2\text{Bi}_2\text{S}_5$,—58
Boulangerite,	Orthorhombic,	$\text{Pb}_5\text{Sb}_4\text{S}_{11}$,—59
Freieslebenite,	Monoclinic,	$(\text{Pb,Ag}_2)_5\text{Sb}_4\text{S}_{11}$,—59
Bournonite,	Orthorhombic,	$\text{Pb}_2\text{Cu}_2\text{Sb}_2\text{S}_8$,—60
Aikinite,	Orthorhombic,	$\text{Pb}_2\text{Cu}_2\text{Bi}_2\text{S}_8$,—61
Jordanite,	Monoclinic,	$\text{Pb}_4\text{As}_2\text{S}_7$,—62
Meneghinite,	Orthorhombic,	$\text{Pb}_4\text{Sb}_2\text{S}_7$,—63
Geocronite,	Orthorhombic,	$\text{Pb}_5\text{Sb}_2\text{S}_8$,—63
Franckeite,	Cubic,	$\text{Pb}_5\text{Sn}_2\text{Sb}_2\text{S}_{12}$,—66

Cylindrite,	Cubic,	$\text{Pb}_6\text{Sn}_6\text{Sb}_2\text{S}_{21}$,—66
Plattnerite,	Tetragonal,	PbPbO_4 ,—82
Massicot,	Orthorhombic,	PbO ,—88
Cotunnite,	Orthorhombic,	PbCl_2 ,—106
Matlockite,	Tetragonal,	Pb_2OCl_2 ,—108
Percylite,	Tetragonal or Cubic,	$\text{Pb}(\text{OH})\text{Cl}.\text{Cu}(\text{OH})\text{Cl}$,—108
Tarnowitzite,	Orthorhombic,	$(\text{Ca},\text{Pb})\text{CO}_3$,—122
CERUSSITE ,	Orthorhombic,	PbCO_3 ,—122
Hydrocerussite,	Hexagonal,	$2\text{PbCO}_3.\text{Pb}(\text{OH})_2$,—125
Phosgenite,	Tetragonal,	$(\text{PbCl})_2\text{CO}_3$,—126
Minium,	Tetragonal?	Pb_2PbO_4 ,—129
ANGLESITE ,	Orthorhombic,	PbSO_4 ,—137
Crocoite ,	Monoclinic,	PbCrO_4 ,—138
Wulfenite ,	Tetragonal,	PbMoO_4 ,—139
Stolzite,	Tetragonal,	PbWO_4 ,—140
Plumbojarosite,	Hexagonal,	$\text{Pb}(\text{Fe}.2\text{OH})_6(\text{SO}_4)_4$,—144
Linarite,	Monoclinic,	$(\text{Pb},\text{Cu})\text{SO}_4.(\text{Pb},\text{Cu})(\text{OH})_2$,—144
Leadhillite ,	Monoclinic,	$\text{PbSO}_4.2\text{PbCO}_3.\text{Pb}(\text{OH})_2$,—145
PYROMORPHITE ,	Hexagonal,	$\text{Pb}_5\text{Cl}(\text{PO}_4)_3$,—172
Mimetite ,	Hexagonal,	$\text{Pb}_5\text{Cl}(\text{AsO}_4)_3$,—173
Endlichite,	Hexagonal,	$\text{Pb}_5\text{Cl}[(\text{As},\text{V})\text{O}_4]_3$,—173
Vanadinite ,	Hexagonal,	$\text{Pb}_5\text{Cl}(\text{VO}_4)_3$,—173
Descloizite,	Orthorhombic,	$(\text{Pb},\text{Zn})(\text{Pb},\text{OH})\text{VO}_4$,—175
Ganomalite,	Tetragonal,	$\text{Pb}_4\text{Ca}_4(\text{PbOH})_2(\text{Si}_2\text{O}_7)_3$,—235
Nasonite,	Tetragonal,	$\text{Pb}_4\text{Ca}_4(\text{PbCl})_2(\text{Si}_2\text{O}_7)_3$,—235
Barysilite,	Hexagonal,	$\text{Pb}_3\text{Si}_2\text{O}_7$,—235•

LITHIUM

Triphylite,	Orthorhombic,	$\text{Li}(\text{Fe},\text{Mn})\text{PO}_4$,—165
Lithiophilite,	Orthorhombic,	LiMnPO_4 ,—166
Amblygonite ,	Triclinic,	$\text{Li}(\text{AlF})\text{PO}_4$,—173
TOURMALINE ,	Hexagonal,	$\text{M}'_9\text{Al}_3(\text{B},\text{OH})_2\text{Si}_4\text{O}_{19}$,—193
Lepidolite ,	Monoclinic,	$(\text{Li},\text{K})_2(\text{F},\text{OH})_2\text{Al}_2\text{Si}_3\text{O}_9$,—219
Zinnwaldite,	Monoclinic,	$(\text{Li},\text{Na})_3(\text{F},\text{OH})_2\text{Al}_3\text{FeSi}_5\text{O}_{16}$, —220
SPODUMENE ,	Monoclinic,	$\text{LiAl}(\text{SiO}_3)_2$,—247
Petalite,	Monoclinic,	$\text{LiAl}(\text{Si}_2\text{O}_5)_2$,—275

MAGNESIUM

Periclase,	Cubic,	MgO ,—83
Brucite ,	Hexagonal,	$\text{Mg}(\text{OH})_2$,—96
Manganobrucite,	Hexagonal,	$(\text{Mg},\text{Mn})(\text{OH})_2$,—96
Ferrobucite,	Hexagonal,	$(\text{Mg},\text{Fe})(\text{OH})_2$,—96
Sellaite,	Tetragonal,	MgF_2 ,—104
Bischofite,	Monoclinic?	$\text{MgCl}_2.6\text{H}_2\text{O}$,—106

Carnallite ,	Orthorhombic,	$\text{MgCl}_2 \cdot \text{KCl} \cdot 6\text{H}_2\text{O}$,—106
Tachydrile ,	Hexagonal,	$2\text{MgCl}_2 \cdot \text{CaCl}_2 \cdot 12\text{H}_2\text{O}$,—107
DOLOMITE ,	Hexagonal,	$\text{CaMg}(\text{CO}_3)_2$,—115
Ankerite ,	Hexagonal,	$(\text{Ca}, \text{Mg}, \text{Fe})\text{CO}_3$,—116
MAGNESITE ,	Hexagonal,	MgCO_3 ,—116
Brunnerite ,	Hexagonal,	$(\text{Mg}, \text{Fe})\text{CO}_3$,—117
Hydromagnesite ,	Monoclinic,	$3\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$,—127
Van't Hoffite ,	Unknown,	$3\text{Na}_2\text{SO}_4 \cdot \text{MgSO}_4$,—132
Langbeinite ,	Cubic,	$\text{K}_2\text{SO}_4 \cdot 2\text{MgSO}_4$,—133
Kieserite ,	Monoclinic,	$\text{MgSO}_4 \cdot \text{H}_2\text{O}$,—149
Epsomite ,	Orthorhombic,	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$,—150
Cupromagnesite ,	Monoclinic,	$(\text{Cu}, \text{Mg})\text{SO}_4 \cdot 7\text{H}_2\text{O}$,—151
Blödit ,	Monoclinic,	$\text{Na}_2\text{Mg}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$,—153
Picromerite ,	Monoclinic,	$\text{K}_2\text{MgCa}_2(\text{SO}_4)_4 \cdot 2\text{H}_2\text{O}$,—153
SPINELS ,	Cubic,	$\text{Mg}(\text{AlO}_2)_2$, etc.,—156
Magnesioferrite ,	Cubic,	$\text{Mg}(\text{FeO}_2)_2$,—159
Sussexite ,	Unknown,	$[(\text{Mn}, \text{Mg})\text{OH}]\text{BO}_2$,—162
BORACITE ,	Orthorhombic and Cubic,	$\text{Mg}_7\text{Cl}_2\text{B}_{16}\text{O}_{30}$,—162
Sulfoborite ,	Orthorhombic,	$4\text{MgHBO}_3 \cdot 2\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$,—164
Adelite ,	Monoclinic,	$\text{Ca}(\text{Mg}, \text{OH})\text{AsO}_4$,—174
Tilasite ,	Monoclinic?	$\text{Ca}(\text{Mg}, \text{F})\text{AsO}_4$,—174
Wagnerite ,	Monoclinic,	$\text{Mg}(\text{Mg}, \text{F})\text{PO}_4$,—175
Lazulite ,	Monoclinic,	$\text{Mg}(\text{Al}, \text{OH})_2(\text{PO}_4)_2$,—176
Struvite ,	Orthorhombic,	$\text{NH}_4\text{MgPO}_4 \cdot 6\text{H}_2\text{O}$,—177
Bobierite ,	Monoclinic,	$\text{Mg}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$,—177
Hoernesite ,	Monoclinic?	$\text{Mg}_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$,—178
Cabrerite ,	Monoclinic?	$(\text{Ni}, \text{Mg})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$,—179
TOURMALINE ,	Hexagonal,	$\text{M}'_3\text{Al}_3(\text{B}, \text{OH})_2\text{Si}_4\text{O}_{19}$,—193
Proectite ,	Monoclinic,	$[\text{Mg}(\text{F}, \text{OH})]_2\text{MgSiO}_4$,—197
Chondrodite ,	Monoclinic,	$[\text{Mg}(\text{F}, \text{OH})]_2\text{Mg}_3(\text{SiO}_4)_2$,—197
Humite ,	Orthorhombic,	$[\text{Mg}(\text{F}, \text{OH})]_2\text{Mg}_5(\text{SiO}_4)_3$,—197
Clinohumite ,	Monoclinic,	$[\text{Mg}(\text{F}, \text{OH})]_2\text{Mg}_7(\text{SiO}_4)_4$,—198
Monticellite ,	Orthorhombic,	CaMgSiO_4 ,—203
Forsterite ,	Orthorhombic,	Mg_2SiO_4 ,—204
OLIVINE ,	Orthorhombic,	$(\text{Mg}, \text{Fe})_2\text{SiO}_4$,—204
Hortonolite ,	Orthorhombic,	$(\text{Fe}, \text{Mg}, \text{Mn})_2\text{SiO}_4$,—205
PYROPE ,	Cubic,	$\text{Mg}_3\text{Al}_2(\text{SiO}_4)_3$,—210
BIOTITE ,	Monoclinic,	$(\text{K}, \text{H})_2(\text{Mg}, \text{Fe})_2(\text{Al}, \text{Fe})_2(\text{SiO}_4)_3$,—215
PHLOGOPITE ,	Monoclinic,	$(\text{K}, \text{H})_3\text{Mg}_3\text{Al}(\text{SiO}_4)_3$,—217
Xanthophyllite ,	Monoclinic,	$\text{H}_8(\text{Mg}, \text{Ca})_{14}\text{Al}_{10}\text{Si}_5\text{O}_{52}$,—221
Brandisite ,	Monoclinic,	$\text{H}_8(\text{Mg}, \text{Ca})_{12}\text{Al}_{12}\text{Si}_5\text{O}_{44}$,—222
Clintonite ,	Monoclinic,	$\text{H}_6(\text{Mg}, \text{Ca})_{10}\text{Al}_{10}\text{Si}_4\text{O}_{30}$,—222
Chlorites ,	Monoclinic,	$\text{H}_4\text{Mg}_2\text{Al}_2\text{SiO}_9$,—223
SERPENTINE ,	Orthorhombic or Monoclinic	$\text{H}_4\text{Mg}_3\text{Si}_2\text{O}_9$,—226
TALC ,	Monoclinic?	$\text{H}_2\text{Mg}_3\text{Si}_4\text{O}_{12}$,—227
Sepiolite ,	Monoclinic?	$\text{H}_4\text{Mg}_2\text{Si}_3\text{O}_{10}$,—228

Garnierite,	Unknown,	$H_2(Ni,Mg)SiO_4$,—229
Deweylite,	Amorphous?	$H_{12}Mg_4Si_3O_{16}$,—229
Genthite,	Amorphous?	$H_{12}Mg_3Ni_2Si_3O_{16}$,—229
Iolite,	Orthorhombic,	$(Mg,Fe)_4Al_8(OH)_2(Si_2O_7)_5$,—236
Geikielite,	Hexagonal,	$MgTiO_3$,—238
PYROXENES,	Orthorhombic and Monoclinic	$Mg_2(SiO_3)_2$, etc.,—240
AMPHIBOLES,	Orthorhombic and Monoclinic,	$(Mg,Fe)_4(SiO_3)_4$, etc.,—250

MANGANESE

Alabandite,	Cubic,	MnS ,—34
Erythrozincite,	Hexagonal,	$(Zn,Mn)S$,—35
Hauerite,	Cubic,	MnS_2 ,—39
Polianite,	Tetragonal,	$MnMnO_4$,—82
PYROLUSITE,	Orthorhombic?	MnO_2 ,—82
Manganosite,	Cubic,	MnO ,—83
MANGANITE,	Orthorhombic,	$MnO.OH$,—92
Manganobrucite,	Hexagonal,	$(Mg,Mn)(OH)_2$,—96
Pyrochroite,	Hexagonal,	$Mn(OH)_2$,—96
Scacchite,	Tetragonal?	$MnCl_2$,—103
RHODOCHRO-	Hexagonal,	$MnCO_3$,—118
SITE,		
Manganocalcite,	Hexagonal,	$(Mn,Ca)CO_3$,—118
Manganosiderite,	Hexagonal,	$(Mn,Fe)CO_3$,—118
Oligonite,	Hexagonal,	$(Fe,Mn)CO_3$,—118
Braunite,	Tetragonal,	$MnMnO_3$,—128
Bixbyite,	Cubic,	$FeMnO_3$,—128
Hausmannite,	Tetragonal,	Mn_2MnO_4 ,—129
Chalcophanite,	Hexagonal,	$(Zn,Mn)Mn_2O_5.2H_2O$,—129
Psilomelane and Wad,	Unknown,	MnO,BaO,H_2O , etc.,—129
Huebnerite,	Monoclinic,	$MnWO_4$,—140
WOLFRAMITE,	Monoclinic,	$(Fe,Mn)WO_4$,—141
Mallardite,	Monoclinic,	$MnSO_4.7H_2O$,—151
Luckite,	Monoclinic,	$(Fe,Mn)SO_4.7H_2O$,—151
Apjohnite,	Cubic,	$MnAl_2(SiO_4)_4.24H_2O$,—154
Dysluite,	Cubic,	$(Zn,Mn)[(Al,Fe)O_2]_2$,—157
FRANKLINITE,	Cubic,	$(Fe,Mn,Zn)(FeO_2)_2$,—158
Jacobsite,	Cubic,	$Mn[(Fe,Mn)O_2]_2$,—159
Sussexite,	Unknown,	$[(Mn,Mg)OH]BO_2$,—162
Natrophilite,	Orthorhombic,	$NaMnPO_4$,—165
Triphylite,	Orthorhombic,	$Li(Fe,Mn)PO_4$,—165
Lithiophilite,	Orthorhombic,	$LiMnPO_4$,—166
Tapiolite,	Tetragonal,	$(Fe,Mn)[(Ta,Nb)O_3]_2$,—168
Mossite,	Tetragonal,	$(Fe,Mn)[(Nb,Ta)O_3]_2$,—168
Tantalite,	Orthorhombic,	$(Fe,Mn)[(Ta,Nb)O_3]_2$,—168

COLUMBITE,	Orthorhombic,	$(\text{Fe}, \text{Mn}) [(\text{Nb}, \text{Ta}) \text{O}_3]_2$,—169
Sarkinite,	Monoclinic,	$\text{Mn}(\text{Mn.OH})\text{AsO}_4$,—174
Triploidite,	Monoclinic?	$\text{Mn}(\text{Mn.OH})\text{PO}_4$,—176
Childrenite,	Orthorhombic,	$(\text{Fe}, \text{Mn})\text{Al}(\text{OH})_2\text{PO}_4 \cdot \text{H}_2\text{O}$,—181
Carpholite,	Monoclinic,	$\text{Mn}(\text{Al}_2\text{OH})_2(\text{SiO}_3)_2$,—196
Helvite,	Cubic,	$(\text{Mn}, \text{Be}, \text{Fe})_7\text{S}(\text{SiO}_4)_3$,—198
Danalite,	Cubic,	$(\text{Fe}, \text{Zn}, \text{Be}, \text{Mn})_7\text{S}(\text{SiO}_4)_3$,—198
Piemontite,	Monoclinic,	$\text{Ca}_2(\text{Mn}, \text{Al})_2(\text{Al.OH})(\text{SiO}_4)_3$,—201
Glaucochroite,	Orthorhombic,	CaMnSiO_4 ,—203
Hortonolite,	Orthorhombic,	$(\text{Fe}, \text{Mg}, \text{Mn})_2\text{SiO}_4$,—205
Knebelite,	Orthorhombic,	$(\text{Mn}, \text{Fe})_2\text{SiO}_4$,—205
Tephroite,	Orthorhombic,	Mn_2SiO_4 ,—205
Trimerite,	Triclinic, (Pseudo-hexagonal),	MnBeSiO_4 ,—205
SPESSARTITE,	Cubic,	$\text{Mn}_3\text{Al}_2(\text{SiO}_4)_3$,—210
Astrophyllite,	Orthorhombic,	$(\text{K}, \text{Na}, \text{H})_4(\text{Fe}, \text{Mn})_4(\text{Si}, \text{Ti})_5\text{O}_{16}$,—237
Pyrophanite,	Hexagonal,	MnTiO_3 ,—239
Schefferite,	Monoclinic,	$(\text{Ca}, \text{Mg})(\text{Fe}, \text{Mn})(\text{SiO}_3)_2$,—244
Jeffersonite,	Monoclinic,	$(\text{Ca}, \text{Mn})(\text{Mg}, \text{Fe}, \text{Zn})(\text{SiO}_3)_2$,—244
Rhodonite,	Triclinic,	$\text{Mn}_2(\text{SiO}_3)_2$,—249
Fowlerite,	Triclinic,	$(\text{Mn}, \text{Fe}, \text{Ca}, \text{Zn}, \text{Mg})_2(\text{SiO}_3)_2$,—249
Babingtonite,	Triclinic,	$(\text{Ca}, \text{Fe}, \text{Mn})_2(\text{SiO}_3)_2$, etc.,—249
Neptunite,	Monoclinic,	$(\text{Na}, \text{K})_2(\text{Fe}, \text{Mn})(\text{Si}, \text{Ti})_5\text{O}_{12}$,—275
Ganophyllite,	Monoclinic,	$\text{Mn}_7(\text{AlO})_2(\text{SiO}_3)_8 \cdot 6\text{H}_2\text{O}$,—279

See also axinite, 213, aenigmatite, 256, and dysanallyte, 273.

MERCURY

Amalgam,	Cubic,	(Ag, Hg) ,—24
Native Mercury,	Cubic,	Hg ,—24
Gold Amalgam,	Cubic,	$(\text{Au}, \text{Hg}, \text{Ag})$,—28
Metacinnabarite,	Cubic,	HgS ,—51
Onofrite,	Cubic,	$\text{Hg}(\text{S}, \text{Se})$,—51
Tiemannite,	Cubic,	HgSe ,—51
CINNABAR,	Hexagonal,	HgS ,—52
TETRAHEDRITE,	Cubic,	$\text{M}''_4\text{R}'''\text{S}_7$,—61
Calomel,	Tetragonal,	Hg_2Cl_2 ,—105

MOLYBDENUM

Molybdenite,	Hexagonal,	MoS_2 ,—32
Molybdite,	Orthorhombic?	$\text{Mo}_3\text{Fe}_3\text{O}_{12} \cdot 7\frac{1}{2}\text{H}_2\text{O}$,—96
Powellite,	Tetragonal,	CaMoO_4 ,—139
Wulfenite,	Tetragonal,	PbMoO_4 ,—139

NEODYMIUM

See didymium, page 300.

NICKEL

Josephinite,	Unknown,	(Fe,Ni) ₅ ,—20
Pentlandite,	Cubic,	(Fe,Ni)S,—35
Millerite,	Hexagonal,	NiS,—36
Niccolite,	Hexagonal,	NiAs,—37
Arite,	Hexagonal,	Ni(As,Sb),—37
Breithauptite,	Hexagonal,	NiSb,—37
Gersdorffite,	Cubic,	NiAsS,—41
Ullmannite,	Cubic,	NiSbS,—41
Chloanthite,	Cubic,	NiAs ₂ ,—42
Wolfachite,	Orthorhombic,	Ni(As,S,Sb) ₂ ,—45
Rammelsbergite,	Orthorhombic,	NiAs ₂ ,—45
Linnæite,	Cubic,	(Ni,Co) ₃ S ₄ ,—56
Bunsenite,	Cubic,	NiO,—83
Winklerite,	Unknown,	(Co,Ni) ₂ O(OH) ₄ ,—94
Zaratite,	Unknown,	NiCO ₃ .2Ni(OH) ₂ .4H ₂ O,—128
Morenosite,	Orthorhombic,	NiSO ₄ .7H ₂ O,—151
Annabergite,	Monoclinic,	Ni ₃ (AsO ₄) ₂ .8H ₂ O,—179
Garnierite,	Unknown,	H ₂ (Ni,Mg)SiO ₄ ,—229

See also native iron, page 19, awaruite, page 20, and pyrrhotite, page 36.

NIOBIUM

Fergusonite,	Tetragonal,	Y(Nb,Ta)O ₄ ,—167
Samarskite,	Orthorhombic,	R'' ₃ R''' ₂ (Nb,Ta) ₆ O ₂ ,—168
Tapiolite,	Tetragonal,	(Fe,Mn)[(Ta,Nb)O ₃] ₂ ,—168
Mossite,	Tetragonal,	(Fe,Mn)[(Nb,Ta)O ₃] ₂ ,—168
Tantalite,	Orthorhombic,	(Fe,Mn)[(Ta,Nb)O ₃] ₂ ,—168
COLUMBITE,	Orthorhombic,	(Fe,Mn)[(Nb,Ta)O ₃] ₂ ,—169
Polymignite,	Orthorhombic,	Ca ₃ (CeO) ₄ (Ti ₂ O ₅) ₅ .Ca(NbO ₃) ₂ , —274

See also yttrotantalite, 167, steenstrupine, 273, dysanallyte, 273, polycrase, 274, and euxenite, 274.

NITROGEN

The following minerals contain nitrogen, which occurs as an essential constituent only in the nitrates and the various ammonium compounds.

Sal Ammoniac,	Cubic,	NH ₄ Cl,—99
SODA NITER,	Hexagonal,	NaNO ₃ ,—109
Niter,	Orthorhombic,	KNO ₃ ,—110
Mascagnite,	Orthorhombic,	(NH ₄) ₂ SO ₄ ,—131
Tschermigite,	Cubic,	(NH ₄) ₃ Al ₂ (SO ₄) ₄ .24H ₂ O,—154
Struvite,	Orthorhombic,	NH ₄ MgPO ₄ .6H ₂ O,—177

See also uraninite, 142.

OSMIUM

Iridosmium,	Hexagonal,	(Os,Ir),—18
Osmiridium,	Hexagonal,	(Ir,Os),—19

See also the other members of the platinum group, page 17.

OXYGEN

Oxygen is an important constituent of many classes of minerals, see page 1. It is therefore present in the vast majority of minerals. The elements, sulphides and analogous compounds, and the haloids do not contain oxygen.

PALLADIUM

Native Palladium,	Cubic,	Pd,—18
Allopalladium,	Hexagonal,	Pd,—19

See also the other members of the platinum group, page 17.

PHOSPHOROUS

Phosphorous is contained in the phosphates, described on pages 165 to 182. See also the lists of the various elements.

PLATINUM

Native Platinum,	Cubic,	Pt,—17
Sperrylite,	Cubic,	PtAs ₂ ,—42

See the other members of the platinum group, page 17.

POLONIUM

See uraninite, page 142.

POTASSIUM

Sylvite,	Cubic,	KCl,—98
Carnallite,	Orthorhombic,	MgCl ₂ .KCl.6H ₂ O,—106
Erythrosiderite,	Hexagonal?	FeCl ₃ .2KCl.H ₂ O,—106
Kremersite,	Hexagonal?	FeCl ₃ .2(K,NH ₄)Cl.H ₂ O,—106
Douglasite,	Orthorhombic?	FeCl ₂ .2KCl.2H ₂ O,—107
Niter,	Orthorhombic,	KNO ₃ ,—110
Glaserite,	Hexagonal,	(K,Na) ₂ SO ₄ ,—131
Arcanite,	Orthorhombic,	(K,Na) ₂ SO ₄ ,—131
Langbeinite,	Cubic,	K ₂ SO ₄ .2MgSO ₄ ,—133

Alunite,	Hexagonal,	$K_2(Al_2OH)_6(SO_4)_4$,—143
Jarosite,	Hexagonal,	$K_2(Fe_2OH)_6(SO_4)_4$,—144
Hanksite,	Hexagonal,	$9Na_2SO_4 \cdot 2Na_2CO_3 \cdot KCl$,—145
Picromerite,	Monoclinic,	$K_2Mg(SO_4)_2 \cdot 6H_2O$,—153
Polyhalite,	Monoclinic?	$K_2MgCa_2(SO_4)_4 \cdot 2H_2O$,—153
Kalinite,	Cubic,	$K_2Al_2(SO_4)_4 \cdot 24H_2O$,—154
Kainite,	Monoclinic,	$MgSO_4 \cdot KCl \cdot 3H_2O$,—154
MICAS,	Monoclinic,	$(K,H)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$, etc.,—214
NEPHELITE,	Hexagonal,	$(Na,K)_8Al_8Si_9O_{34}$,—232
Astrophyllite,	Orthorhombic,	$(K,Na,H)_4(Fe,Mn)_4(Si,Ti)_5O_{16}$, —237
LEUCITE,	Orthorhombic and Cubic,	$K_2Al_2Si_4O_{12}$,—257
ORTHOCLASE,	Monoclinic,	$KAlSi_3O_8$,—259
MICROCLINE,	Triclinic,	$KAlSi_3O_8$,—264
Neptunite,	Monoclinic,	$(Na,K)_2(Fe,Mn)(Si,Ti)_5O_{12}$, —275
Milarite,	Orthorhombic?	$HKCa_2Al_2(Si_2O_5)_6$,—275
APOPHYLLITE,	Tetragonal,	$H_{14}K_2Ca_8(SiO_3)_{16} \cdot 9H_2O$,—280

See also tourmaline, 193, davyne, 233, and aenigmatite, 256.

PRASEODYMIUM

Same as for didymium, page 300.

RHODIUM

See the minerals of the platinum group, page 17.

RUBIDIUM

Small amounts of rubidium are often observed in the minerals containing caesium, page 297.

RUTHENIUM

Occurs in small quantities in the minerals of the platinum group, page 17.

SAMARIUM

See the minerals containing cerium, thorium, and yttrium, pages 299, 315, and 317, respectively.

SCANDIUM

Same as for samarium.

SELENIUM

Selensulphur,	Unknown,	(S,Se),—14
Selenium,	Monoclinic,	Se,—14
Guanajuatite,	Orthorhombic,	$\text{Bi}_2(\text{Se},\text{S})_3$,—31
Clausthalite,	Cubic,	PbSe ,—48
Aguilarite,	Cubic,	$\text{Ag}_2(\text{S},\text{Se})$,—49
Naumannite,	Cubic,	$(\text{Ag}_2,\text{Pb})\text{Se}$,—49
Eucairite,	Cubic,	$(\text{Ag},\text{Cu})_2\text{Se}$,—49
Onofrite,	Cubic,	$\text{Hg}(\text{S},\text{Se})$,—51
Tiemannite,	Cubic,	HgSe ,—51

SILICON

Silicon is an essential constituent of the silicates, see pages 183 to 287, and also under the various elements. It occurs furthermore in the following oxides:

QUARTZ,	Hexagonal,	SiO_2 ,—70
Tridymite,	Orthorhombic,	SiO_2 ,—75
Cristobalite,	Tetragonal,	SiO_2 ,—76
Thorite,	Tetragonal,	ThSiO_4 ,—80
OPAL,	Amorphous,	$\text{SiO}_2 \cdot x\text{H}_2\text{O}$,—89

SILVER

NATIVE SILVER,	Cubic,	Ag,—23
Amalgam,	Cubic,	(Ag,Hg) ,—24
Gold Amalgam,	Cubic,	$(\text{Au},\text{Hg},\text{Ag})$,—28
Dyscrasite,	Orthorhombic,	Ag_3Sb ,—46
Argentite,	Cubic,	Ag_2S ,—48
Jalpaite,	Cubic,	$(\text{Ag},\text{Cu})_2\text{S}$,—49
Aguilarite,	Cubic,	$\text{Ag}_2(\text{S},\text{Se})$,—49
Naumannite,	Cubic,	$(\text{Ag}_2,\text{Pb})\text{Se}$,—49
Eucairite,	Cubic,	$(\text{Ag},\text{Cu})_2\text{Se}$,—49
Hessite,	Cubic,	Ag_2Te ,—49
Stromeyerite,	Orthorhombic,	$(\text{Cu},\text{Ag})_2\text{S}$,—50
Acanthite,	Orthorhombic,	Ag_2S ,—50
Petzite,	Orthorhombic,	$(\text{Ag},\text{Au})_2\text{Te}$,—50
Sylvanite,	Monoclinic,	$(\text{Au},\text{Ag})\text{Te}_2$,—53
Krennerite,	Orthorhombic,	$(\text{Au},\text{Ag})\text{Te}_2$,—54
Miargyrite,	Monoclinic,	AgSbS_2 ,—57
Freieslebenite,	Monoclinic,	$(\text{Pb},\text{Ag}_2)_5\text{Sb}_4\text{S}_{11}$,—59

Proustite,	Hexagonal,	Ag_3AsS_3 ,—59
Pyrargyrite,	Hexagonal,	Ag_3SbS_3 ,—59
TETRAHEDRITE,	Cubic,	$\text{M}''_4\text{R}''_2\text{S}_7$,—61
Stephanite,	Orthorhombic,	$\text{Ag}_{10}\text{Sb}_2\text{S}_8$,—63
Pearceite,	Monoclinic,	$(\text{Ag,Cu})_9\text{AsS}_6$,—63
Polybasite,	Monoclinic,	$(\text{Ag,Cu})_9\text{SbS}_6$,—64
Polyargyrite,	Cubic,	$\text{Ag}_{24}\text{Sb}_2\text{S}_{15}$,—64
Canfieldite,	Cubic,	$\text{Ag}_8(\text{Sn,Ge})\text{S}_6$,—66
Argyrodite,	Cubic,	Ag_8GeS_6 ,—66
Cerargyrite,	Cubic,	AgCl ,—101
Embolite,	Cubic,	$\text{Ag}(\text{Cl,Br})$,—102
Bromyrite,	Cubic,	AgBr ,—102
Iodobromite,	Cubic,	$\text{Ag}(\text{Cl,Br,I})$,—102
Miersite,	Cubic,	AgI ,—102
Iodyrite,	Hexagonal,	AgI ,—102

SODIUM

HALITE,	Cubic,	NaCl ,—99
CRYOLITE,	Monoclinic,	$\text{AlF}_{3.3}\text{NaF}$,—107
Pachnolite,	Monoclinic,	$\text{AlF}_3.\text{NaCaF}_3.\text{H}_2\text{O}$,—108
SODA NITER,	Hexagonal,	NaNO_3 ,—109
Dawsonite,	Monoclinic?	$\text{NaAl}(\text{OH})_2\text{CO}_3$,—125
Northupite,	Cubic,	$\text{MgCO}_3.\text{Na}_2\text{CO}_3.\text{NaCl}$,—126
Thermonatrite,	Orthorhombic,	$\text{Na}_2\text{CO}_3.\text{H}_2\text{O}$,—126
Natron,	Monoclinic,	$\text{Na}_2\text{CO}_3.10\text{H}_2\text{O}$,—126
Trona,	Monoclinic,	$\text{Na}_2\text{CO}_3.\text{NaHCO}_3.2\text{H}_2\text{O}$,—127
Pirssonite,	Orthorhombic,	$\text{Na}_2\text{CO}_3.\text{CaCO}_3.2\text{H}_2\text{O}$,—127
Gay-Lussite,	Monoclinic,	$\text{Na}_2\text{CO}_3.\text{CaCO}_3.5\text{H}_2\text{O}$,—127
Glaserite,	Hexagonal,	$(\text{K,Na})_2\text{SO}_4$,—131
Arcanite,	Orthorhombic,	$(\text{K,Na})_2\text{SO}_4$,—131
Thenardite,	Orthorhombic,	Na_2SO_4 ,—132
Glauberite,	Monoclinic,	$\text{Na}_2\text{SO}_4.\text{CaSO}_4$,—132
Van't Hoffite,	Unknown.	$3\text{Na}_2\text{SO}_4.\text{MgSO}_4$,—132
Natrojarosite,	Hexagonal,	$\text{Na}_2(\text{Fe}.2\text{OH})_6(\text{SO}_4)_4$,—143
Sulphohalite,	Cubic,	$3\text{Na}_2\text{SO}_4.\text{NaCl}.\text{NaF}$,—145
Hanskite,	Hexagonal,	$9\text{Na}_2\text{SO}_4.2\text{Na}_2\text{CO}_3.\text{KCl}$,—145
Mirabilite,	Monoclinic,	$\text{Na}_2\text{SO}_4.10\text{H}_2\text{O}$,—146
Blödite,	Monoclinic,	$\text{Na}_2\text{Mg}(\text{SO}_4)_2.4\text{H}_2\text{O}$,—153
Mendozite,	Cubic,	$\text{Na}_2\text{Al}_2(\text{SO}_4)_4.24\text{H}_2\text{O}$,—154
BORAX,	Monoclinic,	$\text{Na}_2\text{B}_4\text{O}_7.10\text{H}_2\text{O}$,—163
Ulexite,	Monoclinic,	$\text{NaCaB}_5\text{O}_{10}.6\text{H}_2\text{O}$,—163
Beryllonite,	Orthorhombic,	NaBePO_4 ,—165
Natrophilite,	Orthorhombic,	NaMnPO_4 ,—165
Paragonite,	Monoclinic,	$\text{H}_2\text{NaAl}_3(\text{SiO}_4)_3$,—219
NEPHELITE,	Hexagonal,	$(\text{Na,K})_8\text{Al}_8\text{Si}_9\text{O}_{34}$,—232
Cancrinite,	Hexagonal,	$\text{H}_6(\text{Na}_2,\text{Ca})_4(\text{NaCO}_3)_2\text{Al}_8\text{Si}_9\text{O}_{36}$, —233

Davyne,	Hexagonal,	$(\text{Na}_2, \text{Ca}, \text{K}_2)_{16}(\text{NaCO}_3, \text{NaSO}_4, \text{Cl})_{11}\text{Al}_{25}\text{Si}_{24}\text{O}_{96},$ —233
Sodalite ,	Cubic,	$\text{Na}_4\text{Al}_2(\text{AlCl})(\text{SiO}_4)_3,$ —233
Noselite,	Cubic,	$\text{Na}_4\text{Al}_2[\text{Al}(\text{NaSO}_4)](\text{SiO}_4)_3,$ —234
Häüynite,	Cubic,	$\text{Na}_2\text{CaAl}_2[\text{Al}(\text{NaSO}_4)](\text{SiO}_4)_3,$ —234
Lāzurite ,	Cubic,	$(\text{Na}_2, \text{Ca})_2\text{Al}_2[\text{Al}(\text{NaSO}_4, \text{NaS}_3, \text{Cl})](\text{SiO}_4)_3,$ —234
Astrophyllite,	Orthorhombic,	$(\text{K}, \text{Na}, \text{H})_4(\text{Fe}, \text{Mn})_4(\text{Si}, \text{Ti})_5\text{O}_{16},$ —237
Pectolite ,	Monoclinic,	$(\text{Ca}, \text{Na}_2)_2(\text{SiO}_3)_2,$ —246
Jadeite,	Monoclinic,	$\text{NaAl}(\text{SiO}_3)_2,$ —247
Acmite,	Monoclinic,	$\text{NaFe}(\text{SiO}_3)_2,$ —248
Soda-Orthoclase,	Monoclinic,	$(\text{Na}, \text{K})\text{AlSi}_3\text{O}_8,$ —263
ALBITE and	Triclinic,	$\text{NaAlSi}_3\text{O}_8,$ etc.,—266
PLAGIOCLASES,		
SCAPOLITE ,	Tetragonal,	$\text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{25},$ etc.,—269
Eudidymite,	Monoclinic,	$\text{HNaBeSi}_3\text{O}_8,$ —271
Epididymite,	Orthorhombic,	$\text{HNaBeSi}_3\text{O}_8,$ —271
Catapleiite,	Monoclinic and Hexagonal	$\text{H}_4\text{Na}_2\text{ZrSi}_3\text{O}_{11},$ —273
Elpidite,	Orthorhombic,	$\text{H}_6\text{Na}_2\text{ZrSi}_6\text{O}_{18},$ —273
Eudialyte,	Hexagonal,	$\text{Na}_{13}(\text{Ca}, \text{Fe})_6(\text{Si}, \text{Zr})_{20}\text{O}_{52}\text{Cl},$ —273
Lorenzenite,	Orthorhombic,	$\text{Na}_2\text{Si}_2(\text{Ti}, \text{Zr})_2\text{O}_9,$ —274
Neptunite,	Monoclinic,	$(\text{Na}, \text{K})_2(\text{Fe}, \text{Mn})(\text{Si}, \text{Ti})_5\text{O}_{12},$ —275
Thomsonite ,	Orthorhombic,	$2(\text{Ca}, \text{Na}_2)\text{Al}_2(\text{SiO}_4)_2 \cdot 5\text{H}_2\text{O},$ —276
Hydronephelite,	Hexagonal?	$\text{HNa}_2\text{Al}_3(\text{SiO}_4)_3 \cdot 3\text{H}_2\text{O},$ —277
Natrolite ,	Orthorhombic and Monoclinic,	$\text{Na}_2\text{Al}(\text{AlO})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O},$ —277
Mesolite,	Monoclinic,	$\text{Na}_2\text{Al}(\text{AlO})(\text{SiO}_3)_3 \cdot 2\text{H}_2\text{O},$ etc.,—278
ANACLITE ,	Cubic,	$\text{Na}_2\text{Al}_2(\text{SiO}_3)_4 \cdot 2\text{H}_2\text{O},$ —279
Mordenite,	Monoclinic,	$(\text{K}_2, \text{Na}_2, \text{Ca})\text{Al}_5\text{Si}_{10}\text{O}_{24} \cdot 7\text{H}_2\text{O},$ —282
STILBITE ,	Monoclinic,	$(\text{Ca}, \text{Na}_2)\text{Al}_2\text{Si}_8\text{O}_{16} \cdot 6\text{H}_2\text{O},$ —283
Gmelinite,	Hexagonal,	$\text{Na}_2\text{Al}_2\text{Si}_6\text{O}_{16} \cdot 8\text{H}_2\text{O},$ etc.,—286

See also tourmaline, 193, steenstrupine, 273, and dysanalyte, 273.

STRONTIUM

STRONTIANITE ,	Orthorhombic,	$\text{SrCO}_3,$ —121
CELESTITE ,	Orthorhombic,	$\text{SrSO}_4,$ —134
Bartocelstite,	Orthorhombic,	$(\text{Sr}, \text{Ba})\text{SO}_4,$ —135
Brewsterite,	Monoclinic,	$\text{H}_4(\text{Sr}, \text{Ba})\text{Al}_2(\text{SiO}_3)_6 \cdot 3\text{H}_2\text{O},$ —282

SULPHUR

Sulphur is an essential constituent of the sulphides, sulphates, and allied compounds, see pages 29 to 66, 133 to 154, and under the various elements. It occurs also in the following:

NATIVE	Orthorhombic,	S,—13
SULPHUR,		
Selensulphur,	Unknown,	(S,Se),—14
Kermesite,	Monoclinic,	$\text{Sb}_2\text{S}_2\text{O}$,—97
Helvite,	Cubic,	$(\text{Mn,Be,Fe})_7\text{S}(\text{SiO}_4)_3$,—198
Danalite,	Cubic,	$(\text{Fe,Zn,Be,Mn})_7\text{S}(\text{SiO}_4)_3$,—198
Davyne,	Hexagonal,	$(\text{Na}_2,\text{Ca,K}_2)_{16}(\text{NaCO}_3,\text{NaSO}_4,\text{Cl})_{11}\text{Al}_{25}\text{Si}_{24}\text{O}_{96}$,—233
Noselite,	Cubic,	$\text{Na}_4\text{Al}_2[\text{Al}(\text{NaSO}_4)](\text{SiO}_4)_3$,—234
Haüynite,	Cubic,	$\text{Na}_2\text{CaAl}_2[\text{Al}(\text{NaSO}_4)](\text{SiO}_4)_3$,—234
Lazurite,	Cubic,	$(\text{Na}_2,\text{Ca})_2\text{Al}_2[\text{Al}(\text{NaSO}_4,\text{NaS}_3,\text{Cl})(\text{SiO}_4)_3]$,—234
Thaumasite,	Hexagonal,	$\text{Ca}_3\text{SCSiO}_{10} \cdot 15\text{H}_2\text{O}$,—287

TANTALUM

The tantalum minerals usually contain niobium, which see, page 309.

TELLURIUM

Native Tellurium,	Hexagonal,	Te,—15
Tetradymite,	Hexagonal,	$\text{Bi}_2\text{Te}_2\text{S}$,—31
Altaite,	Cubic,	PbTe ,—48
Hessite,	Cubic,	Ag_2Te ,—49
Petzite,	Orthorhombic,	$(\text{Ag,Au})_2\text{Te}$,—50
Sylvanite,	Monoclinic,	$(\text{Au,Ag})\text{Te}_2$,—53
Calaverite,	Monoclinic,	AuTe_2 ,—54
Krennerite,	Orthorhombic,	$(\text{Au,Ag})\text{Te}_2$,—54
Nagyagite,	Orthorhombic,	$\text{Au}_2\text{Sb}_2\text{Pb}_{10}\text{Te}_6\text{S}_{15}$,—54
Tellurite,	Orthorhombic,	TeO_2 ,—68

THALLIUM

Lorandite, TlAsS_2 ,—57; see also sphalerite, page 33.

THORIUM

Thorite,	Tetragonal,	ThSiO_4 ,—80
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See also uraninite, 142, monazite, 167, and aeschynite, 274.

TIN

Native Tin,	Hexagonal,	Sn,—16
Stannite,	Tetragonal,	$\text{Cu}_2\text{FeSnS}_4$,—65
Canfieldite,	Cubic,	$\text{Ag}_8(\text{Sn,Ge})\text{S}_6$,—66
Franckeite,	Unknown,	$\text{Pb}_5\text{Sn}_2\text{Sb}_2\text{S}_{12}$,—66
Cylindrite,	Unknown,	$\text{Pb}_6\text{Sn}_6\text{Sb}_2\text{S}_{21}$,—66
CASSITERITE,	Tetragonal,	SnO_2 or SnSnO_4 ,—80

TITANIUM

Brookite,	Orthorhombic,	TiO_2 ,—76
Anatase,	Tetragonal,	TiO_2 ,—76
RUTILE,	Tetragonal,	TiO_2 or TiTiO_4 ,—77
Pseudobrookite,	Orthorhombic,	$\text{Fe}(\text{TiO}_4)_3$,—207
Astrophyllite,	Orthorhombic,	$(\text{K,Na,H})_4(\text{Fe,Mn})_4(\text{Si,Ti})_5\text{O}_{16}$, —237
Perovskite,	Pseudo-cubic,	CaTiO_3 ,—238
Geikielite,	Hexagonal,	MgTiO_3 ,—238
Pyrophanite,	Hexagonal,	MnTiO_3 ,—239
Ilmenite,	Hexagonal,	FeTiO_3 ,—239
TITANITE,	Monoclinic,	CaSiTiO_5 ,—271
Zirkelite,	Monoclinic,	$\text{Ca}(\text{Zr,Ti})_2\text{O}_5$,—273
Benitoite,	Hexagonal,	$\text{BaTiSi}_3\text{O}_9$,—274
Lorenzenite,	Orthorhombic,	$\text{Na}_2\text{Si}_2(\text{Ti,Zr})_2\text{O}_9$,—274
Neptunite,	Monoclinic,	$(\text{Na,K})_2(\text{Fe,Mn})(\text{Si,Ti})_5\text{O}_{12}$, —275

See also schorlomite and melanite, 215, hornblende, 253, tscheffkinitite, 273, dysanallyte, 273, polymignite, 274, aeschynite, 274, polycrase, 274, and euxenite, 274.

TUNGSTEN

Tungstite,	Orthorhombic,	$\text{WO}_3 \cdot \text{H}_2\text{O}$,—68
Scheelite,	Tetragonal,	CaWO_4 ,—139
Stolzite,	Tetragonal,	PbWO_4 ,—140
Huebnerite,	Monoclinic,	MnWO_4 ,—140
WOLFRAMITE,	Monoclinic,	$(\text{Fe,Mn})\text{WO}_4$,—141
Ferberite,	Monoclinic,	FeWO_4 ,—142

URANIUM

Uraninite,	Cubic,	$\text{UO}_3, \text{UO}_2, \text{PbO}$, etc.,—142
Autunite,	Orthorhombic,	$\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$,—182
Uranospinite,	Orthorhombic,	$\text{Ca}(\text{UO}_2)(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$,—182
Torbnerite,	Tetragonal,	$\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$,—182
Zeunerite,	Tetragonal,	$\text{Cu}(\text{UO}_2)_2(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$,—182

Uranotile,	Triclinic,	$\text{CaU}_2\text{Si}_2\text{O}_{11} \cdot 5\text{H}_2\text{O}$,—287
Gummite,	Amorphous?	$(\text{Pb,Ca,Ba})\text{U}_3\text{SiO}_{12} \cdot 5\text{H}_2\text{O}$,—287

See also yttrotantalite, 167, samarskite, 168, polycrase, 274, and euxenite, 274.

VANADIUM

Endlichite,	Hexagonal,	$\text{Pb}_5\text{Cl}[(\text{As,V})\text{O}_4]_3$,—173
Vanadinite,	Hexagonal,	$\text{Pb}_5\text{Cl}(\text{VO}_4)_3$,—173
Descloizite,	Orthorhombic,	$(\text{Pb,Zn})(\text{Pb.OH})\text{VO}_4$,—175

See also roscoelite, 218.

YTTRIUM

Xenotime,	Tetragonal,	YPO_4 ,—166
Fergusonite,	Tetragonal,	$\text{Y}(\text{Nb,Ta})\text{PO}_4$,—167
Yttrotantalite,	Orthorhombic,	$\text{Y}_4(\text{Ta}_2\text{O}_7)_3$,—167
Samarskite,	Orthorhombic,	$\text{R}''_3\text{R}'''_2(\text{Nb,Ta})_6\text{O}_{21}$,—168
Gadolinite,	Monoclinic,	$\text{Fe}[\text{Be}(\text{Y.O})\text{SiO}_4]_2$,—193

See also yttrotitanite, 272, steenstrupine, 273, polymignite, 274, polycrase, 274, euxenite, 274, and the lists under the other rare earths.

ZINC

Native Zinc.	Hexagonal,	Zn ,—20
SPHALERITE ,	Cubic,	ZnS ,—33
Wurtzite,	Hexagonal,	ZnS ,—35
Erythrozincite,	Hexagonal,	$(\text{Zn,Mn})\text{S}$,—35
TETRAHEDRITE ,	Cubic,	$\text{M}''_4\text{R}'''_2\text{S}_7$,—61
Zincite ,	Hexagonal,	ZnO ,—84
SMITHSONITE ,	Hexagonal,	ZnCO_3 ,—117
Monheimite,	Hexagonal,	$(\text{Zn,Fe})\text{CO}_3$,—118
Hydrozincite,	Unknown,	$\text{ZnCO}_3 \cdot 2\text{Zn}(\text{OH})_2$,—125
Aurichalcite,	Monoclinic,	$2(\text{Zn,Cu})\text{CO}_3 \cdot 3(\text{Zn,Cu})(\text{OH})_2$, —125
Chalcophanite,	Hexagonal,	$(\text{Zn,Mn})\text{Mn}_2\text{O}_5 \cdot 2\text{H}_2\text{O}$,—129
Goslarite,	Orthorhombic,	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$,—150
Gahnite ,	Cubic,	$\text{Zn}[(\text{Al,Fe})\text{O}_2]_2$,—157
Dysluite,	Cubic,	$(\text{Zn,Mn})[(\text{Al,Fe})\text{O}_2]_2$,—157
FRANKLINITE ,	Cubic,	$(\text{Fe,Mn,Zn})(\text{FeO}_2)_2$,—158
Adamite,	Orthorhombic,	$\text{Zn}(\text{Zn.OH})\text{AsO}_4$,—175
Descloizite,	Orthorhombic,	$(\text{Pb,Zn})(\text{Pb.OH})\text{VO}_4$,—175
Köttigite,	Monoclinic?	$(\text{Zn,Co})_3(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$,—179
HEMIMORPHITE ,	Orthorhombic,	$\text{H}_2\text{Zn}_2\text{SiO}_5$,—186
Clinohedrite,	Monoclinic,	$\text{H}_2\text{ZnCaSiO}_5$,—187

Danalite,	Cubic,	$(\text{Fe,Zn,Be,Mn})_7\text{S}(\text{SiO}_4)_3$,—198
Willemite,	Hexagonal,	Zn_2SiO_4 ,—206
Hardystonite,	Tetragonal,	$\text{Ca}_2\text{ZnSi}_2\text{O}_7$,—235
Fowlerite,	Triclinic,	$(\text{Mn,Fe,Ca,Zn,Mg})_2(\text{SiO}_3)_2$,—249

ZIRCONIUM

Baddeleyite,	Monoclinic,	ZrO_2 ,—77
ZIRCON ,	Tetragonal,	ZrSiO_4 ,—79
Zirkelite,	Monoclinic,	$\text{Ca}(\text{Zr,Ti})_2\text{O}_5$,—273
Catapleiite,	Monoclinic and Hexagonal.	$\text{H}_4\text{Na}_2\text{ZrSi}_3\text{O}_{11}$,—273
Elpidite,	Orthorhombic,	$\text{H}_6\text{Na}_2\text{ZrSi}_6\text{O}_{18}$,—273
Eudialyte,	Hexagonal,	$\text{Na}_{13}(\text{Ca,Fe})_6(\text{Si,Zr})_{20}\text{O}_{52}\text{Cl}$,—273
Lorenzenite,	Orthorhombic,	$\text{Na}_2\text{Si}_2(\text{Ti,Zr})_2\text{O}_9$,—274

See also astrophyllite, 237, polymignite, 274, and aeschynite, 274.

INDEX

Figures in heavy type are page references to descriptions.

A

Acanthite, 47, **50**, 312
Achroite, **195**
Acmite, 241, **248**, 314
Actinium, 293
Actinolite, 251, **252**
 schist, 253
Adamantine spar, 85
Adamas, 5
Adamite, 174, **175**, 295, 317
Adelite, 174, 306
Adularia, 261
Aegirite, 241, **248**
 -augite, 248
Aenigmatite, 251, **256**
Aeschynite, **274**, 299
Agalmatolite, 231
Agate, 70, **74**
 varieties, 74
Agricolite, 207, **208**, 296
Aguilarite, 46, **49**, 312
Aikinite, 60, **61**, 296, 300, 304
Akermanite, 236
Alabandite, 33, **34**, 307
Alabaster, 146, 147
Albertite, 290
Albite, 259, 265, **266**, 314
Alexandrite, 162
Algodonite, **45**, 295, 299
Allanite, 201
Allemontite, **16**, 294, 295
Allopalladium, 17, **19**, 310
Allophane, **287**, 294
Almandine spinel, 156
Almandite, 208, **210**
Alstonite, 121
Altaite, 46, **48**, 304, 315

Alum group, 154
 stone, 143
Aluminates, 155
Aluminite, **152**, 293
Aluminium, 293
Alunite, **143**, 293, 311
Amalgam, **24**, 308, 312
 gold, **28**, 301, 312
 native, 24
 silver, **24**
Amazonite, 264
Amazonstone, 264
Amber, **290**
Amblygonite, **173**, 293, 301, 305
Ambroid, 291
Amesite, **223**
Amethyst, **73**
 oriental, 85
Amianthus, 253
Ammonium alum, 154
Amphibole group, 250, 294, 298,
 304, 307
Amphigene, 257
Anaclite, **279**, 314
Anatase, 70, **76**, 316
Andalusite, **187**, 293
Andesine, 259, 265, **267**
Andradite, 208, **211**
Anglesite, 133, **137**, 305
Anhydrite, **133**, 298
 region, 101
Ankerite, **111**, **116**, 297, 303, 306
Annabergite, **177**, **179**, 295, 309
Anomite, 216
Anorthite, 259, 265, **268**, 208
Anorthoclase, 259, **264**
Anthophyllite, 250, **251**
Anthracite coal, 291, 292

Anthraconite, 113
 Antigorite, 226, 230
 Antimonite, 30
 Antimonnickel, 37
 Antimony, 14, 15, 294
 arsenical, 16
 glance, 30
 gray, 30
 native, 15, 294
 nickel glance, 41
 Apatite, 170, 298, 301
 Aphanese, 176
 Aphrosiderite, 225
 Apthitalite, 132
 Apjohnite, 154, 307
 Aplome, 211
 Apophyllite, 280, 311
 Aquamarine, 258
 Aragonite, 110, 111, 119, 297
 Arcanite, 131, 310, 313
 Arfvedsonite, 251, 255
 Argentine, 113
 Argentite, 46, 48, 312
 Argillaceous hematite, 87
 Argon, 294
 Argyrodite, 66, 301, 313
 Arite, 33, 37, 309
 Arkansite, 76
 Arsenic, 14, 15, 295
 native, 15, 295
 Arsenical gold ore, 30
 antimony, 16
 Arsenite, 69
 Arsenolite, 69, 295
 Arsenopyrite, 38, 43, 295, 302
 Asbestos, amphibole, 253
 long fibered, 253
 serpentine, 226
 short fibered, 226
 Asparagus stone, 171
 Asphalt, 289
 Asphaltum, 289
 Astrakanite, 153
 Astrophyllite, 237, 304, 308, 311,
 314, 316
 Atacamite, 108, 300
 Augite, 240, 245
 basaltic, 246
 common, 246

Aurichalcite, 123, 125, 300, 317
 Auripigment, 30
 Automolite, 157
 Autunite, 182, 298, 316
 Aventurine, 74
 oligoclase, 267
 Awaruite, 20
 Axinite, 213, 297
 Azurite, 123, 124, 300

B

Babingtonite, 241, 249, 308
 Baddeleyite, 70, 77, 318
 Balas spinel, 156
 Banded agate, 74
 Barium, 295
 Barkevikite, 255
 Barnhardtite, 54, 300
 Barite, 133, 135, 295
 Barium feldspar, 263
 Barandite, 179
 Barsowite, 206, 207
 Bartocelstite, 133, 135, 295, 314
 Barylite, 235, 295
 Barysilite, 235, 305
 Barytes, 135
 Barytocalcite, 123, 295, 297
 Barytophyllite, 223
 Basanite, 75
 Bastite, 241
 Bauxite, 94, 293
 Beauxite, 94
 Bell-metal ore, 65
 Benitoite, 274, 295, 316
 Bergmannite, 278
 Beryl, 257, 294, 296, 297
 common, 258
 Beryllium, 296
 Beryllonite, 165, 296, 313
 Bieberite, 150, 151, 299
 Biotite, 215, 304, 306
 Bischofite, 106, 305
 Bisilicates, 183
 Bismite, 69, 70, 296
 Bismuth, 14, 16, 296
 glance, 31
 native, 16, 296
 ocher, 70

Bismuthinite, 20, 31, 296
 Bismutite, 125, 296
 Bituminous coal, 291, 292
 limestone, 114
 Bixbyite, 128, 303, 307
 Blackband, 119
 hematite, 129
 jack, 33
 lead, 11
 oxide of manganese, 82
 sand, 159, 161
 spinel, 157
 Blende, 33
 Blöditte, 153, 306, 313
 Blood-stone, 74
 Blue carbonate of copper, 124
 earth, 291
 iron-earth, 177
 spinel, 156
 stone, 151
 vitriol, 151
 Boart, 10
 Bobierite, 177, 306
 Bog iron ore, 95
 Boleite, 108
 Bonephosphate, 172
 Boracite, 162, 296, 306
 Borates, 155
 Borax, 163, 296, 313
 Boric acid, 91
 Bornite, 54, 55, 300, 302
 Boron, 296
 Boronatocalcite, 163
 Bort, 5, 10
 Bortz, 10
 Bosjemanite, 154
 Botryolite, 192
 Boulangerite, 58, 59, 294, 304
 Bournonite, 60, 294, 300, 304
 Bragite, 167
 Brandisite, 221, 222, 306
 Braunite, 128, 307
 Brazilite, 77
 Breithauptite, 33, 37, 294, 309
 Breunnerite, 111, 117, 303, 306
 Brevicite, 278
 Brewsterite, 282, 296, 314
 Brimstone, 13
 Brittle silver ore, 63

Brochantite, 144, 300
 Bröggerite, 142
 Bromargyrite, 102
 Bromine, 297
 Bromlite, 111, 121, 295, 297
 Bromyrite, 98, 102, 297, 313
 Bronzite, 240, 242
 Brookite, 70, 76, 316
 Brown clay iron stone, 95
 hematite, 95
 Brucite, 96, 305
 Bunsenite, 83, 309
 Buratite, 125
 Burmite, 290
 Bustamite, 249
 Byssolite, 253
 Bytownite, 259, 265, 268

C

Cabrerite, 177, 179, 306
 Cadmium, 297
 oxide, 83, 297
 Caesium, 297
 Cairngorm stone, 73
 Calamine, 117, 118, 186
 Calaverite, 53, 54, 301, 315
 Calc tufa, 114
 Calcareous sinter, 114
 Calciostrontianite, 121
 Calcite, 110, 111, 297
 varieties, 113
 Calcium, 297
 oxalate, 288
 Calspar, 111
 Caliche, 109
 Calomel, 105, 308
 Campylite, 173
 Cancrinite, 231, 233, 313
 Canfieldite, 66, 301, 313, 316
 Cannel coal, 292
 Cap quartz, 73
 Cape ruby, 210
 Carbon, 3, 10, 298
 Carbonado, 10
 Carbonates, 110
 Carbuncle, 210
 Carnallite, 106, 306, 310
 region, 101

- Carnelian, 74
 Carpholite, 195, 196, 308
 Cassiterite, 77, 80, 316
 ordinary, 81
 Castorite, 274
 Catapleiite, 273, 314, 318
 Cat's eye, 74, 162
 Cedarite, 291
 Celandonite, 220
 Celestite, 133, 134, 314
 Celsian, 259, 269, 295
 Cerargyrite, 98, 101, 313
 Ceresin, 289
 Cerite, 202, 299
 Cerium, 299
 Cerussite, 111, 122, 305
 Cerusite, 122
 Ceylonite, 157
 Chabazite, 285
 Chalcanthite, 151, 300
 Chalcedony, 70, 74
 Chalcocite, 46, 47, 49, 300
 Chalcophanite, 129, 307, 317
 Chalcophyllite, 180, 300
 Chalcopyrite, 54, 55, 300, 302
 Chalcotrichite, 89
 Chalk, 113, 114
 French, 227
 Chalybite, 118
 Chamosite, 225
 Chathamite, 42
 Chert, 75
 Chessylite, 124
 Chiastolite, 187
 Childrenite, 181, 303, 308
 Chile saltpeter, 109
 China clay, 230
 Chloanthite, 38, 42, 295, 309
 Chlorastrolite, 213
 Chlorine, 299
 Chlorite, 223, 224, 294, 306
 Chloritic quartz, 74
 Chloritoid, 221, 222, 304
 Chlormelanite, 247
 Chloro-apatite, 171
 Chlorcalcite, 103
 Chloropal, 231
 Chlorspinel, 156
 Chondrodite, 197, 301, 306
 Chrismatite, 289
 Christianite, 284
 Chromates, 131
 Chrome diopside, 243
 iron, 158
 spinel, 157
 Chromic iron ore, 158
 Chromium, 299
 Chromite, 155, 158, 299, 303
 Chrysoberyl, 166, 161, 293, 296
 Chrysocolla, 212, 300
 Chrysolite, 204
 Chrysophane, 222
 Chrysoprase, 74
 Chrysotile, 226
 asbestos, 253
 Cinnabar, 50, 51, 52, 308
 Cinnamon stone, 209
 Citrine, 74
 Clausthalite, 46, 48, 304, 312
 Clay, china, 230
 iron stone, 119
 Cleiophane, 34
 Clementite, 225
 Cleveite, 142
 Clinocllore, 223, 224
 Clinoclasite, 176, 300
 Clinohedrite, 186, 187, 298, 317
 Clinohumite, 197, 198, 301, 306
 Clinozoisite, 199, 200, 298
 Clintonite, 221, 222, 306
 Clouded agate, 74
 Coals, 291, 292
 Cobalt, 299
 bloom, 178
 glance, 40
 pyrites, 56
 Cobaltite, 38, 40, 295, 299
 Colemanite, 164, 296, 298
 Columbite, 168, 169, 303, 308, 309
 Columbium, 299
 Common opal, 90
 salt, 99
 Compact hematite, 87
 limestones, 113
 limonite, 95
 Comptonite, 276
 Cookeite, 220
 Copalite, 291

Copiapite, 152, 303
 Copper, 20, 21, 299
 glance, 49
 gray ore, 61
 native, 21, 299
 nickel, 37
 pyrites, 55
 shot, 22
 silver glance, 50
 uranite, 182
 Copperas, 151
 Coquimbite, 152, 303
 Coquina, 114
 Cordierite, 236
 Corneous lead, 126
 Corundophillite, 223
 Corundum, 84, 293
 Cosalite, 58, 296, 304
 Cossyrite, 256
 Cotunnite, 105, 106, 305
 Covellite, 51, 300
 Cristobaltite, 70, 76, 312
 Crocalite, 278
 Crocidolite, 256
 Crocoite, 133, 138, 299, 305
 Cronstedite, 225
 Crude oil, 288
 Cryolite, 107, 293, 301, 313
 Crystalline dolomite, 116
 limestone, 114
 Cummingtonite, 253
 Cuprite, 88, 300
 Cupromagnesite, 150, 151, 300, 306
 Cuproscheelite, 140
 Cyanite, 189, 293
 Cyndrite, 66, 305, 316
 Cymophane, 162

D

Damourite, 218
 Danaite, 44
 Danalite, 198, 296, 303, 308, 315,
 318
 Danburite, 206, 207, 297
 Daphanite, 225
 Datholite, 192
 Datolite, 191, 192, 297, 298
 Datolithe, 192

Dyane, 232, 233, 314, 315
 Dawsonite, 125, 313
 Delessite, 225
 Demantoid, 211
 Descloizite, 174, 175, 305, 317
 Desmine, 283
 Deweylite, 225, 229, 307
 Diabantite, 225
 Diallage, 240, 243
 Diamond, 3, 298
 black, 10
 carat, 3
 cut, 10
 drill, 11
 Diaphorite, 58
 Diaspore, 92, 293
 Diatomaceous earth, 90
 Dichroite, 236
 Didymium, 300
 Diopside, 240, 243
 chrome, 243
 Dioptase, 211, 300
 Diorthosilicic acid, 183
 Dipyre, 270
 Disterrite, 222
 Disthene, 189
 Dog-tooth spar, 113
 Dolomite, 111, 115, 297, 306
 Dolomitic limestones, 113
 Domeykite, 45, 46, 295, 300
 Douglasite, 106, 107, 303, 310
 Dry bone, 117
 Dudleyite, 221
 Dufrenite, 176, 303
 Dufrenoyite, 58, 301
 Dumortierite, 185, 296
 Dysanallyte, 273
 Dyscrasite, 45, 46, 294, 312
 Dysluite, 155, 157, 307, 317

E

Edenite, 254
 Edingtonite, 277, 279, 295
 Eisennickelkies, 35
 Eistein, 107
 Elaeolite, 232
 Elaterite, 290
 Elements, 3

Elpidite, 273, 314, 318
 Embolite, 98, 102, 297, 313
 Emerald, 258
 nickel, 128
 oriental, 85
 Emery, 84, 85
 Emmonite, 121
 Emplectite, 57, 296, 300
 Enargite, 64, 295, 300
 Endlichite, 170, 173, 305, 317
 Enstatite, 240, 241
 Epidote, 109, 200, 293, 298, 303
 Epididymite, 271, 296, 314
 Epistilbite, 282
 Epsomite, 149, 150, 306
 Epsom salt, 150
 Erbium, 300
 Erythrite, 177, 178, 295, 299
 Erythrosiderite, 106, 310
 Erythrozincite, 33, 35, 307, 317
 Essonite, 209
 Eucairite, 46, 49, 312
 Euchroite, 180, 300
 Euclase, 191, 192, 296
 Eucolite, 273
 Eucryptite, 232
 Eudialyte, 273, 314, 318
 Eudidymite, 271, 296, 314
 Eulytite, 207, 296
 Euralite, 225
 Euxenite, 274
 Exanthalite, 146

F

False topaz, 74
 Famatinite, 64, 65
 Fargite, 278
 Fassaite, 240, 245
 Faujasite, 281
 Fayalite, 203, 205, 304
 Feldspar, 259
 barium, 263
 glassy, 261
 group, 259
 lime, 268
 soda, 268
 ordinary, 262

potash, 260
 soda, 266
 lime, 267
 Feldspars, 259, 294
 monoclinic, 259, 260
 triclinic, 259, 264
 Felsite, 262
 Felspar, 260
 Ferberite, 138, 142, 303, 316
 Fergusonite, 166, 167, 309, 317
 Ferrobucite, 96, 305
 Ferrocobaltite, 41
 Ferrogoslarite, 151
 Ferruginous quartz, 74
 Fibrolite, 188
 Fichtelite, 290
 Fiorite, 90
 Fire opal, 90
 Flint, 75
 Flos ferri, 119, 120
 Fluellite, 106, 293
 Fluor-apatite, 171
 Fluorine, 301
 Fluorite, 103, 297, 301
 Fluor spar, 103
 Fontainebleau limestone, 113
 Fool's gold, 39
 Forsterite, 203, 204, 306
 Fortification agate, 74
 Fowlerite, 241, 249, 308, 318
 Franckeite, 66, 304, 316
 Franklinite, 155, 158, 303, 307, 317
 Freibergite, 62
 Freieslebenite, 58, 59, 294, 304, 312
 French chalk, 227
 Frenzelite, 31
 Fuchsite, 260

G

Gadolinite, 191, 193, 296, 303, 317
 Gahnite, 155, 157, 317
 Galactite, 278
 Galena, 46, 47, 304
 Galenite, 47
 Gallium, 301
 Ganomalite, 235, 305
 Ganophyllite, 279, 308

- Garnet, 208, 294, 298, 304
 black, 211
 calcium-aluminium, 209
 -iron, 211
 common, 211
 chromium-calcium, 211
 group, 208
 iron-aluminium, 210
 magnesium-aluminium, 210
 manganese-aluminium, 210
 Garnierite, 225, 229, 307, 309
 Gay-Lussite, 127, 297, 313
 Gedanite, 291
 Gedrite, 250, 252
 Gehlenite, 236, 237
 Geikielite, 238, 307, 316
 Genthite, 225, 229, 307
 Geocronite, 63, 304
 Germanium, 301
 Gersdorffite, 38, 41, 295, 309
 Geysierite, 90
 Gibbsite, 91, 92, 293
 Gilsonite, 290
 Glaserite, 131, 310, 313
 Glauberite, 132, 297, 313
 Glauber salt, 146
 Glaucochroite, 203, 308
 Glaucodote, 38, 44, 295, 299, 302
 Glauconite, 220
 Glaucophanite, 251, 255
 Glucinum, 301
 Gmelinite, 285, 286, 314
 Goethite, 92, 93, 303
 Gold, 20, 25, 301
 amalgam, 28, 301, 308
 carat, 28
 fool's, 39
 free milling, 25
 native, 25, 301
 Goshenite, 258
 Goslarite, 149, 150, 317
 Grahamite, 290
 Granular limestone, 114
 quartz, 75
 Graphite, 3, 11, 298
 Graphitic tellurium, 53
 granites, 262
 Green carbonate of copper, 124
 sand, 220
 Greenockite, 33, 35, 297
 Greisen, 81
 Grossularite, 208, 209
 Grothite, 271, 272
 Grünerite, 253
 Guanajuatite, 30, 31, 296, 312
 Guano, 171
 Gummite, 287, 317
 Gymnite, 229
 nickel, 229
 Gypsite, 147
 Gypsum, 146, 298
- ## H
- Halite, 98, 99, 313
 Haloids, 98
 Halotrichite, 154, 303
 Hanksite, 154, 311, 313
 Hardystonite, 235, 298, 318
 Harmotome, 282, 283, 284, 296
 Hartite, 290
 Hatchettite, 289
 Hauerite, 38, 39, 307
 Hausmannite, 129, 307
 Häuynite, 234
 Häuynite, 233, 234, 314, 315
 Heavy spar, 135
 Hedenbergite, 240, 244
 Hedyphane, 173
 Helium, 302
 Heliotrope, 74
 Helvite, 198, 296, 303, 308, 315
 Hematite, 84, 86, 302
 Hemimorphite, 185, 186, 317
 Hercynite, 155, 157
 Herderite, 174, 175, 296
 Hessite, 46, 49, 312, 315
 Hessonite, 209
 Heulandite, 281
 Hexagonite, 252
 Hiddenite, 247
 Hoernesite, 177, 178
 Holmesite, 222, 306
 Holmite, 222
 Homilite, 191, 193, 297, 298, 303
 Horn mercury, 105
 silver, 101

Hornblende, 251, 253
 basaltic, 254
 common, 254
 Hornstone, 75
 Horse flesh ore, 55
 Hortonolite, 203, 205, 306; 308
 Hövellite, 98
 Huebernite, 138, 140, 307, 316
 Humboldtite, 237
 Humboldtine, 288
 Humite, 196, 197, 301, 306
 Hyacinth, 79, 80
 Hyalite, 90
 Hyalophane, 259, 263, 295
 Hydrargillite, 92
 Hydraulic limestone, 113
 Hydrocerussite, 123, 125, 305
 Hydrofranklinite, 129
 Hydrogen, 302
 Hydromagnesite, 127, 306
 Hydronephelite, 277, 314
 Hydrophane, 90
 Hydrophilite, 103, 297
 Hydrorhodonite, 249
 Hydroxides, 89
 Hypersthene, 240, 242
 Hydrozincite, 12, 125, 317
 Hystatite, 239

I

Ice, 67
 Iceland spar, 111, 113
 Idrialite, 290
 Idocrase, 202
 Iglite, 123
 Ilmenite, 237, 238, 239, 304, 316
 Ilvaite, 196, 298, 303
 Indicolite, 195
 Indigolite, 195
 Indium, 302
 Inesite, 282
 Infusorial earth, 90
 Iodargyrite, 102
 Iodine, 302
 Iodobromite, 98, 102, 297, 302, 313
 Iodyrite, 98, 102, 302, 313
 Iolite, 236, 304, 307
 Iridium, 17, 18, 302
 native, 18, 302

Iridosmine, 18
 Iridosmium, 17, 18, 302, 310
 Iron, 19, 302
 alum, 154
 cross, 40
 meteoric, 19
 native, 19, 302
 roses, 86
 schefferite, 244
 spinel, 157
 terrestrial, 19
 titaniferous, 239
 Isinglass, 217
 Itacolumite, 75

J

Jacobsite, 155, 159, 303, 307
 Jade, 247, 252
 Jadeite, 241, 247, 314
 Jalpaite, 46, 49, 312
 Jamesonite, 58, 294, 304
 Jargon, 79
 Jarosite, 143, 144, 303, 311
 Jasper, 70, 74
 Jeffersonite, 240, 244, 308
 Jet, 292
 Jordanite, 62, 295, 304
 Josephinite, 20, 309

K

Kainite, 154, 311
 region, 101
 Kalinite, 154, 293, 311
 Kaliophilite, 232
 Kaolin, 230
 Kaolinite, 230, 294
 Katoforite, 255
 Kelyphite, 210
 Kermesite, 97, 294, 315
 Kieserite, 149, 306
 region, 101
 Knebelite, 203, 205, 308
 Knopite, 238
 Köttigite, 177, 179, 299, 317
 Kraurite, 176
 Kremersite, 106, 310
 Krennerite, 53, 54, 301, 312, 315
 Kunzite, 248
 Kyanite, 189

L

Labradorescence, 268
 Labradorite, 259, 265, 268
 Labrador spar, 268
 Land plaster, 147
 Langbeinite, 132, 133, 306, 310
 Lanthanum, 304
 Lapis-lazuli, 234
 Lasurite, 234
 Laterite, 94
 Laumontite, 286
 Lautarite, 109, 302
 Lawrencite, 103
 Lawsonite, 195, 196, 298
 Lazulite, 176, 293, 306
 Lazurite, 233, 234, 314, 315
 Lead, 20, 304
 black, 11
 glance, 47
 native, 20, 304
 Leadhillite, 145, 305
 Lepidolite, 215, 219, 297, 301, 305
 Lepidomelane, 216
 Leptochlorites, 225
 Leucaugite, 240, 246
 Leucite, 257, 294, 311
 Leucopyrite, 44
 Leucoxene, 239, 272
 Libethenite, 174, 175, 300
 Lievrite, 196
 Lignite, 291, 292
 Limestone, 113
 varieties, 113
 Lime uranite, 182
 Limonite, 95, 303
 varieties, 95
 Linarite, 144, 300, 305
 Linnaeite, 56, 299, 309
 Lintonite, 276
 Lithographic limestone, 113
 Lithiophilite, 165, 166, 305, 307
 Lithium, 305
 Lodestone, 159
 Löllingite, 38, 44, 295, 302
 Lorandite, 57, 295, 315
 Lorenzenite, 274, 314, 316, 318
 Loxoclase, 262
 Luzonite, 64

Luckite, 150, 151, 317
 Lydian stone, 75

M

Macle, 187
 Magnesian limestone, 113
 Magnesioferrite, 155, 159, 303, 306
 Magnesite, 111, 116, 306
 Magnesium alum, 154
 Magnetic iron ore, 159
 Magnetite, 155, 159, 303
 Magnoferrite, 159
 Malachite, 123, 124, 300
 Malacolite, 240
 Malacon, 79
 Mallardite, 150, 151, 307
 Manganandalusite, 188
 Manganblende, 34
 Manganese alum, 154
 black oxide, 82
 Magnesium, 305
 Manganhedenbergite, 244
 Manganiferous epidote, 201
 Manganite, 92, 93, 307
 Manganites, 128
 Mangankies, 39
 Manganobrucite, 96, 305, 307
 Manganocalcite, 110, 118, 297, 307
 Manganocolumbite, 169
 Manganopectolite, 247
 Manganosiderite, 111, 118, 303, 307
 Manganosite, 83, 307
 Manganotantalite, 169
 Marble, 113, 114
 serpentine, 226
 Marcasite, 38, 42, 302
 Marceline, 128
 Margarite, 221
 Marialite, 269, 270
 Marl, 113, 114
 Marshite, 105, 300, 302
 Martite, 87
 Mascagnite, 131, 309
 Masonite, 223
 Massicot, 88, 305
 Matlockite, 108, 305
 Meerschauum, 228
 Meigen's test, 113, 120

Meionite, 269, 270
 Melaconite, 88, 89, 300
 Melanite, 211
 Melanterite, 150, 151, 303
 Melilite, 236, 237
 Mellite, 288
 Menaccanite, 239
 Mendozite, 154, 313
 Meneghinite, 62, 63, 304
 Mercury, 20, 24, 308
 native, 24, 308
 Meroxene, 216
 Mesitite, 117
 Mesolite, 277, 278, 314
 Mesotype, 278
 Metachlorite, 225
 Metacinnabarite, 50, 51, 308
 Metamorphosed limestone, 114
 Metasilicic acid, 183
 Metastilbite, 283
 Mexican onyx, 114
 Miargyrite, 57, 294, 312
 Mica, 214, 294, 311
 A, 218
 amber, 217
 black, 215
 brittle, 221
 bronze, 217
 group, 214
 lithium, 219
 -iron, 220
 magnesium, 217
 -iron, 215
 pearl, 221
 potash, 217
 ribbon, 218
 ruby, 218
 ruled, 218
 rum, 218
 sheet, 219
 sodium, 219
 wedge, 218
 white, 217
 Micanite, 219
 Microcline, 259, 264, 311
 soda, 264
 Microsomite, 233
 Miersite, 98, 102, 302, 313
 Milarite, 275, 311

Milk opal, 90
 Milky quartz, 74
 Millerite, 33, 36, 309
 Mimetite, 170, 173, 295, 305
 Mineral oil, 288
 pitch, 289
 wax, 289
 Minium, 129, 305
 Mirabilite, 146, 313
 Mispickel, 43
 Misy, 152, 153
 Mizzonite, 270
 Mohawkite, 46
 Molydbates, 138
 Molybdenite, 32, 308
 Molybdic ochre, 96
 Molybdite, 96, 308
 Molysite, 105, 303
 Monazite, 166, 167, 299
 Monheimite, 111, 118, 303, 317
 Monticellite, 203, 298, 306
 Moonstone, 261, 266
 Mordenite, 282, 314
 Morenosite, 149, 151, 309
 Morion, 73
 Moss agate, 74
 Mossite, 168, 307, 309
 Mountain cork, 253
 leather, 253
 wood, 253
 Muscovite, 215, 217

N

Nacrite, 230
 Nagyagite, 53, 54, 294, 301, 304, 315
 Nail-head spar, 113
 Nantokite, 105, 300
 Nasonite, 233, 305
 Natroalunite, 143
 Natrojarosite, 143, 144, 303, 313
 Natrolite, 277, 314
 Natron, 126, 313
 Natronborocalcite, 163
 Natrophyllite, 165, 307, 313
 Naumannite, 46, 49, 304, 312
 Needle zeolite, 277
 Neodymium, 309
 Nepheline, 232

Nephelite, 231, 232, 294, 311, 313
 Nephrite, 252 [316]
 Neptunite, 275, 304, 308, 311, 314,
 Nevyanskite, 19
 Newportite, 223
 Niccolite, 33, 37, 295, 309
 Nickel, 309
 bloom, 178
 glance, 41
 sepiolite, 229
 gymmite, 229
 Nigrine, 78
 Niobium, 309
 Niter, 109, 110, 309, 310
 Nitrates, 109
 Nitrogen, 309
 Nivenite, 142
 Nontronite, 230, 231, 304
 Nordmarkite, 185
 Normal dolomite, 116
 Northupite, 126, 313
 Nosean, 234
 Noselite, 233, 234, 314, 315
 Noumeite, 229

O

Ocherous limonite, 95
 Octahedrite, 76
 Oldhamite, 33, 297
 Oligoclase, 259, 265, 267
 Oligonite, 111, 118, 119, 303, 307
 Olivenite, 174, 174, 295, 300
 Olivine, 203, 204, 304, 306
 Omphacite, 243
 Onofrite, 50, 51, 308, 312
 Onyx, 74, 114
 marble, 114
 Mexican, 114
 Oolitic iron ore, 87
 limestone, 114
 Opal, 89, 312
 varieties, 90
 Ophicalcite, 226
 Orangite, 80
 Organic compounds, 288
 Orpiment, 30, 295
 Orthite, 199, 201, 298, 299, 303
 Orthochlorites, 225

Orthoclase, 259, 260, 311
 ordinary, 262
 soda, 259, 263
 Orthosilicic acid, 183
 Osmium, 310
 Osmiridium, 17, 19, 302, 310
 Osteolite, 171
 Ottrelite, 221, 222
 Ouvarovite, 211
 Oxalite, 288, 304
 Oxide of cadmium, 83
 Oxides, 67
 Oxychlorides, 108
 -fluorides, 108
 -sulphides, 97
 Ozocerite, 289
 Ozokerite, 289
 Oxygen, 310

P

Pachnolite, 108, 301, 313
 Palladium, 17, 18, 19, 310
 native, 18, 19, 310
 Pandermite, 164, 296, 298
 Paraffin, 289
 Paragonite, 215, 219, 313
 Paramelaconite, 89, 90
 Pargasite, 254
 Patrinite, 61
 Pearceite, 63, 300, 313
 Pearl spar, 115
 Peat, 291, 292
 Pectolite, 241, 246, 314
 Pencatite, 128
 Pencil stone, 231
 Penninite, 223, 224
 Pentasilicic acid, 183
 Pentlandite, 33, 35, 302, 309
 Percylite, 108, 305
 Periclase, 83, 305
 Peridot, 204
 Peristerite, 266
 Perovskite, 237, 238, 298, 316
 Perowskite, 238
 Perthite, 262
 Petalite, 274, 305
 Petroleum, 288
 Petzite, 47, 50, 301, 312, 315

- Phacelite, 232
 Phacolite, 285
 Pharmacolite, 180, 295
 Pharmacosiderite, 180, 295, 303
 Phenacite, 203, 205, 296
 Phengite, 218
 Phillipsite, 283, 284
 Phlogopite, 215, 217, 306
 Pholerite, 230
 Phosgenite, 126, 305
 Phosphate rock, 171
 Phosphates, 165
 Phosphorite, 171
 Phosphorous, 310
 Phyllite, 223
 Picroilmenite, 239
 Picrotitanite, 239
 Picotite, 155, 157
 Picromerite, 153, 306, 311
 Piemontite, 199, 201, 298, 308
 Pirssonite, 127, 297, 313
 Pisanite, 150, 151, 303
 Pisolitic limestone, 114
 Pistacite, 200
 Pistomesite, 117
 Pitchblende, 142
 Plagioclases, 259, 260, 265, 298, 314
 Plagionite, 58, 294
 Plasma, 74
 Plaster of Paris, 149
 Platiniridium, 17, 302
 Platinum, 17, 310
 iron, 17
 native, 17, 310
 Platternite, 77, 82, 305
 Pleonaste, 155, 157
 Plumbago, 11
 Plumbites, 128
 Plumbojarosite, 143, 144, 303, 305
 Polianite, 77, 82, 307
 Pollucite, 297
 Polonium, 310
 Polyargyrite, 64, 313
 Polybasite, 63, 64, 294, 300, 313
 Polycrase, 274
 Polyhalite, 153, 311
 region, 101
 Polymignite, 274, 309
 Polysilicic acid, 183
 Potash alum, 154
 feldspar, 260
 Potassium, 310
 Powellite, 138, 139, 298, 308
 Prase, 74
 Praseodymium, 311
 Precious opal, 90
 serpentine, 226
 Predazzite, 128
 Prehnite, 213, 294, 298
 Prochlorite, 223, 224
 Prolectite, 197, 306
 Proustite, 59, 295, 313
 Pseudobrookite, 207, 304, 316
 Pseudoleucite, 257
 Psilomelante, 129, 296, 307
 Purple copper ore, 55
 Pyrargyrite, 59, 294, 313
 Pyrite, 38, 39, 302
 Pyrites, 39
 capillary, 36
 cobalt, 56
 copper, 55
 iron, 39
 magnetic, 36
 spear, 42
 tin, 65
 white iron, 42
 Pyrochlore, 273
 Pyrochroite, 96, 307
 Pyrolusite, 82, 307
 Pyromorphite, 170, 172, 305
 Pyrope, 208, 210, 306
 Pyrophanite, 238, 239, 308, 316
 Pyrophyllite, 230, 231, 294
 Pyropissite, 290
 Pyrostibite, 97
 Pyrrhotite, 33, 36, 302
 Pyroxenes, 240, 250, 298, 304, 307
 Pyrrhite, 274
- Q
- Quartz, 70, 312
 varieties, 73
 Quartzite, 75
 Quicksilver, 24

R

Rammelsbergite, 38, 45, 295, 309
 Ranite, 277
 Realgar, 29, 295
 Red antimony, 97
 clay, 87
 clay ironstone, 87
 copper ore, 88
 hematite, 87
 iron ore, 86
 ocher, 87
 oxide of copper, 88
 zinc, 84
 silver ore, 59
 zinc ore, 84
 Reddle, 87
 Rensselaerite, 227
 Residual limonite, 95
 Resin opal, 90
 Retinite, 291
 Rhätzite, 189
 Rhodium, 311
 Rhodochrosite, 111, 118, 307
 Rhodonite, 241, 249, 308
 Rhodotilite, 282
 Rhyacolite, 261
 Riband jasper, 75
 Richterite, 251, 253
 Riebeckite, 251, 256
 Ripidolite, 224
 Rock crystal, 73
 gypsum, 147
 salt, 99
 Roepperite, 205
 Roscoelite, 218
 Rose quartz, 73
 Rothkupferkies, 37
 Rubellite, 195
 Rubicelle, 156
 Rubidium, 311
 Ruby, 84, 85
 cape, 210
 copper ore, 88
 silver ore, 59
 spinel, 156
 Rumpfite, 225
 Ruthenium, 311
 Rutilated quartz, 74
 Rutile, 77, 316

S

Safflorite, 38, 44, 295, 299
 Sal ammoniac, 98, 99, 309
 Salite, 240
 Salmite, 223
 Salt, common, 99
 regions, 101
 rock, 99
 Saltpeter, 109, 110
 Chile, 109
 Salvadorite, 151
 Samarium, 311
 Samarskite, 168, 309, 317
 Sand, 75
 black, 159, 161
 green, 220
 Sandstone, 75
 Sanidine, 261
 Saponite, 225, 229
 Sapphire, 84, 85
 Sarcolite, 271
 Sard, 74
 Sardonyx, 74
 Sarkinite, 174, 308
 Sartorite, 57
 Sassolite, 91, 296
 Satin spar, 113, 146, 147
 Scacchite, 103, 307
 Saussurite, 200
 Scandium, 312
 Scapolite, 269, 270, 294, 298, 314
 Schalenblende, 35
 Scheelite, 138, 139, 298, 316
 Schefferite, 240, 244, 308
 Schönite, 153
 Schorl, 195
 Schorlomite, 211
 Schungite, 3, 12, 298
 Schwatzite, 62
 Scleroclase, 57, 304
 Scolecite, 277, 278
 Scorodite, 179, 295, 303
 Seladonite, 220
 Selenite, 146, 147
 Selenium, 14, 312
 Selenosulphur, 14, 312, 315
 Seligmannite, 60
 Sellaite, 103, 104, 301, 305
 Senarmontite, 69, 294

Sepiolite, 225, 228, 306
 nickel, 229
 Sericite, 218
 Serpentine, 225, 226, 306
 common, 226
 fibrous, 226
 marble, 226
 precious, 226
 Seybertite, 222
 Siberite, 195
 Siderite, 111, 118, 303
 Silicates, 183
 Silicified wood, 73
 Silicious sinter, 90
 Silicon, 312
 Sillimantite, 188, 293
 Silver, 20, 23, 312
 glance, 48
 native, 23, 312
 Simonyite, 153
 Sipyllite, 167
 Sislerskite, 18
 Sismondine, 223
 Skutterudite, 45, 295, 299
 Smaltite, 36, 41, 295, 299
 Smithsonite, 111, 117, 297, 317
 Smoky quartz, 73
 Snow, 67
 Soapstone, 227
 Soda, 126
 alum, 154
 niter, 109, 309, 313
 Sodalite, 233, 294, 314
 Soda-orthoclase, 259, 263, 314
 Sodium, 313
 Sommervillite, 237
 Spathic iron, 118
 Spathiopyrite, 44
 Specular iron ore, 86
 Specularite, 86
 Sperrylite, 38, 42, 295, 310
 Spessartite, 208, 210, 308
 Sphaerocobaltite, 111, 119, 299
 Sphalerite, 32, 33, 297, 317
 Sphene, 271, 272
 Spinel, 155, 156, 293, 303, 306
 varieties, 156
 Spodumene, 241, 247, 294, 305
 Spreustein, 278

Stagmites, 114
 Stalactites, 114
 Stalagmites, 114
 Stannite, 65, 300, 302, 316
 Staurolite, 184, 293, 303
 Steatite, 227
 Steenstrupine, 273, 296
 Stelznerite, 144, 300
 Stephanite, 63, 294, 313
 Stibnite, 30, 294
 Stilbite, 281, 283, 314
 Stinkstone, 113
 Stolzite, 138, 140, 305, 316
 Stream tin, 81
 Strengite, 179, 303
 Strigovite, 225
 Striped jasper, 75
 Stromeyerite, 47, 50, 300, 312
 Strontianite, 111, 121, 314
 Struvite, 177, 306, 309
 Succinite, 290
 Sulfoborite, 164, 296, 316
 Sulphates, 131
 Sulphides, 29
 Sulphohalite, 145, 301, 313
 Sulphur, 13, 315
 native, 13, 315
 Sunstone, 267
 Sussexite, 162, 296, 306, 307
 Sylvanite, 53, 301, 312, 315
 Sylvite, 98, 310
 Symplectite, 177, 178, 303

T

Tabular spar, 244
 Tachydrile, 106, 107, 297, 306
 Tachyhydrite, 107
 Talc, 225, 227, 230, 306
 Tantalite, 168, 303, 307, 309
 Tantalum, 315
 Tapolite, 168, 307, 309
 Tarnowitzite, 111, 122, 297, 305
 Tasmanite, 291
 Tellurite, 68, 315
 Tellurium, 14, 15, 315
 graphic, 53
 native, 15, 315
 Tennantite, 62

Tenorite, 89, 300
 Tephroite, 203, 205, 308
 Terra alba, 149
 Tetradymite, 31, 296, 315
 Tetrahedrite, 61, 294, 295, 300,
 302, 308, 313, 317
 Tetrasilicates, 183
 Tetrasilicic acid, 183
 Texasite, 128
 Thallium, 315
 Thaumansite, 287, 315
 Thenardite, 131, 132, 313
 Thermonatrite, 126, 313
 Thinolite, 114
 Thomsenolite, 108, 301
 Thomsonite, 276, 314
 Thorates, 183
 Thorite, 77, 80, 312, 316
 Thorium, 316
 Thulite, 199
 Thuringite, 225
 Tiemannite, 50, 51, 308, 312
 Tiger's eye, 74, 256
 Tilasite, 174, 401, 306
 Tile ore, 89
 Tin, 16, 316
 native, 16, 316
 ore, 80
 ore deposits, 81, 140, 141
 pyrites, 65
 stone, 80, 81
 stream, 80, 81
 wood, 81
 Tinkal, 163
 Titanates, 183
 Titanic iron ore, 239
 Titaniferous iron, 230
 Titanite, 271, 298, 316
 Titanium, 316
 Titanomorphite, 239, 272
 Topaz, 190, 293, 301
 false, 74
 oriental, 85
 Topazolite, 211
 Torbernite, 182, 300, 316
 Touchstone, 75
 Tourmaline, 193, 293, 297, 305, 306
 tongs, 194, 195
 Travertine, 114

Tremolite, 251, 252
 Tridymite, 75, 312
 Trimerite, 203, 205, 308
 Triphane, 247
 Triphylite, 165, 303, 305, 307
 Triplite, 174, 176, 301, 303
 Triploidite, 174, 176, 308
 Tripolite, 90
 Trisilicates, 183
 Trisilicic acid, 183
 Troilite, 33, 35, 302
 Trona, 127, 313
 Troostite, 206
 Tscheffkinite, 273, 296
 Tschermigite, 154, 309
 Tungstates, 138
 Tungsten, 316
 Tungstite, 68, 316
 Turkey fat, 117
 Turnerite, 167
 Turquoise, 181, 293
 Turquoise, 181
 Tyrite, 167
 Tysonite, 105, 299, 301

U

Uintahite, 290
 Ulexite, 163, 296, 298, 313
 Ultramarine, 234
 Ullmannite, 38, 41, 294, 309
 Unisilicates, 183
 Uralite, 246, 255
 Uralitization, 255
 Uraninite, 142, 293, 294, 316
 Uranium, 316
 Uranocircite, 182
 Uranophane, 287
 Uranospinite, 182, 316
 Uranotantalite, 168
 Uranotile, 287, 317
 Urao, 127
 Urpethite, 289
 Uvarovite, 208, 211, 299
 Uwarowite, 211

V

Valentinite, 69, 294
 Vanadinite, 170, 173, 305, 317
 Vanadium, 317

Van't Hoffite, 132, 306, 313
 Variegated copper ore, 55
 Variscite, 179, 293
 Verd-antique, 226
 Vermilion, natural, 52
 Vesuvianite, 202, 294, 298, 301
 Vivianite, 178, 303
 Volcanite, 14
 Voltzite, 97

W

Wad, 130, 307
 Wagnerite, 174, 175, 301, 306
 Walchowite, 291
 Waluewite, 221
 Warthite, 153
 Washingtonite, 239
 Water, 67
 Wavellite, 180, 293
 Wellsite, 283, 284, 296
 Wernerite, 269, 270
 Wheel ore, 60
 Whewellite, 288, 298
 White lead ore, 122
 Whiteneyite, 45, 295, 299
 Willemite, 203, 206, 318
 Winklerite, 94, 299, 309
 Witherite, 111, 122, 295
 Wolfachtite, 38, 45, 309
 Wolfram, 141
 Wolframite, 138, 141, 303, 307, 316
 Wollastonite, 240, 244
 Wood opal, 90
 tin, 86
 Wulfenite, 138, 139, 305, 308
 Wurtzite, 32, 33, 35, 297, 316

X

Xanthophyllite, 221, 306
 Xanthosiderite, 94, 303
 Xenotime, 166, 317

Y

Yellow copperas, 152
 copper ore, 55
 quartz, 74
 Yttrium, 317
 Yttrioilmenite, 168
 Yttrotantalite, 167, 317
 Yttrotitanite, 272

Z

Zaratite, 128, 309
 Zeolites, 276, 294, 298
 Zeunerite, 182, 300, 316
 Zietrisikite, 289
 Zinc, 20, 317
 blende, 33
 bloom, 125
 native, 20, 317
 spinel, 157
 Zinckenite, 57
 Zincite, 83, 48, 317
 Zinkenite, 57, 294, 304
 Zircon, 77, 79, 318
 Zirconium, 318
 Zinnwaldite, 215, 220, 301, 305
 Zirconates, 183
 Zirkelite, 273, 316, 318
 Zoisite, 199, 293, 298
 Zwitter, 81



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